Newsletter No. 5 September 1, 1984

IHW

INTERNATIONAL HALLEY WATCH

THE INTERNATIONAL HALLEY WATCH NEWSLETTER

Issue No. 5 September 1, 1984

IHW Leader, Western Hemisphere: Ray L. Newburn

IHW Leader, Eastern Hemisphere: Jurgen Rahe

IHW Deputy Leader: Murray Geller

IHW Newletter Editor: Stephen J. Edberg

Editorial

This is the fifth IHW Newsletter. Future issues will appear on an irregular or bi-yearly basis. Our hope is to maintain open lines of communication between the IHW Lead Center, discipline specialists, observers, flight projects, and other interested readers. We invite short contributions on scientific, instrumental, or social aspects of preparations for the Halley apparition. Please submit items of interest to the editor at the address below.

S. J. Edberg, Editor
Jet Propulsion Laboratory
California Institute of Technology
MS T-1166
4800 Oak Grove Drive
Pasadena, CA 91109, USA
(818) 354-6085

This publication was prepared by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

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IHW ADDRESSES

Astrometry

Dr. D. K. Yeomans
Jet Propulsion Lab., Caltech
4800 Oak Grove Dr., MS 264-664
Pasadena, CA 91109 USA

Dr. R. M. West
European Southern Observatory
8046 Garching bei Munchen
FEDERAL REPUBLIC OF GERMANY

Dr. R. S. Harrington
U. S. Naval Observatory
34th & Massachusetts Ave.
Washington, DC 20390 USA

Dr. B. Marsden
Center for Astrophysics
60 Garden Street
Cambridge, MA 02138 USA

Infrared Spectroscopy

Dr. R. R. Knacke
Earth & Space Sci. Dept.
SUNY at Stony Brook
Stony Brook, NY 11794

Dr. T. Encrenaz
Observatoire de Paris
Section d'Astrophysique
92190 Meudon, FRANCE

Large-Scale Phenomena

Dr. J. C. Brandt
Code 680
Goddard Space Flight Center
Greenbelt, MC 20771 USA

Dr. M. Niedner
Code 685
Goddard Space Flight Center
Greenbelt, MD 20771 USA

Dr. J. Rahe
Dr.-Remeis-Sternwarte
Sternwartstrasse 7
D-8600 Bamberg
FEDERAL REPUBLIC OF GERMANY

Near-Nucleus Studies

Dr. S. Larson
Lunar and Planetary Lab.
University of Arizona
Tucson, AZ 85721 USA

Dr. J. Rahe (Listed under L-SP)

Dr. Z. Sekanina
Jet Propulsion Lab., Caltech
4800 Oak Grove Dr., MS 183-401
Pasadena, CA 91109 USA

Photometry

Dr. M. A'Hearn
Astronomy Program
University of Maryland
College Park, MD 20742 USA

Dr. V. Vanysek
Department of Astronomy
Charles University
Svedska 8, 150 00
Praha 5, CZECHOSLOVAKIA

Radio Studies

Dr. W. Irvine and
Dr. F. P. Schloerb
Dept. of Physics & Astron.
University of Massachusetts
Amherst, MA 01003 USA

Dr. E. Gerard
Observatoire de Paris
92190 Meudon, FRANCE

Dr. Ron D. Brown and
Dr. Peter Godfrey
Department of Chemistry
Monash University
Wellington Rd, Clayton
Victoria, AUSTRALIA 3168

Spectroscopy

Dr. S. Wyckoff and
Dr. P. Wehinger
Physics Department
Arizona State University
Tempe, AZ 85281 USA

Dr. M. C. Festou
Institut d'Astrophysique
de Paris
98 bis Boulevard Arago
75014 Paris, FRANCE

IHW Lead Centers

Jet Propulsion Lab., Caltech
4800 Oak Grove Dr., MS T1166
Pasadena, CA 91109
USA

Dr.-Remeis-Sternwarte
Sternwartstrasse 7
D-8600 Bamberg
FEDERAL REPUBLIC OF GERMANY

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LETTERS

Sir:

A brief comment on Dr. Tatum's letter (IHW Newsletter No. 4). Halley often spelled his name 'Horley' or 'Hawley', so this is probably the best pronunciation. 'Halley' (rhyming with 'tally') is acceptable. 'Hayley' is not. This refers to a pop group.

Recall the old rhyme:

Of all the comets in the sky
There's none like Comet Halley.
We see it with the naked eye,
And periodically.

In view of the unfavourable coming return, Dr. John Mason, my co-author in a book, has amended this to

Of all the comets in the sky
There's none like Comet Hawley.
We'll see it with the naked eye,
But this time, rather poorly!

Patrick Moore,
Farthings,
West Street,
Selsey, Sussex
UNITED KINGDOM

Sir:

I wish to point out another item that may be confusing to some researchers concerning P/Crommelin. It is true that Brian Marsden's CATALOG OF COMETARY ORBITS does list P/Crommelin for the year 1928 as Forbes III. If anyone should use S. K. Vsekhsvyatskii's PHYSICAL CHARACTERISTICS OF COMETS in either the Russian version or the English translation NASA TT F-80, Vsekhsvyatskii has listed Forbes as being 1928 IV and gives the designation 1928 III to a Comet Giacobini which is not listed in the CATALOG OF COMETARY ORBITS as there is some doubt as to whether it really existed.

Robert G. Warren
61733 Locust Road
South Bend, Indiana 46614 USA

FROM THE LEAD CENTERS

A great deal has happened since the deadline for the last Newsletter, virtually all of it good. The number of professional astronomers expressing an interest in working with the IHW has risen to 875 from 47 countries. Some plan to work in more than one net, so there are 1298 net members.

At the Inter-Agency Consultative Group (IACG) meeting in Kagoshima, Japan

last December all the flight projects agreed to submit their data pool tapes to the "Halley Archives" (see the contribution on the IACG by R. Reinhard, p. 3). They will deliver the data tapes within two years of the encounters.

The Crommelin trial run seems to have gone well. Weather was generally good in the Southern Hemisphere and North America, mixed in Asia and poor in Europe. Although final results won't be available for some months, more people than we expected successfully observed the comet.

The European Space Agency [ESA] will be making a substantial contribution in support of the Astrometry Net of the IHW through March 1986. This was done in recognition of the fact that "real time" high precision astrometry required for the Giotto flight project is a considerably more extensive undertaking than the normal work associated with a strictly ground-based program. We appreciate the help very much.

R. Newburn
J. Rahe
M. Geller

MEETING OF EUROPEAN PARTICIPANTS IN THE IHW

Following an invitation by M. Festou and E. Gerard and the undersigned, European participants in the International Halley Watch met on May 10, 1984, at the Institut d'Astrophysique in Paris, France. Representativies of CHUKCC (Comet Halley U. K. Coordinating Committee) were J. Eaton (Leicester) and J. Zarnecki (Canterbury); also attending was J. Rahe (Bamberg). The main topic of the discussions concerned the outcome of the "trial run" of the IHW on Comet Crommelin in March, 1984, and problems that became apparent as a result of this "dry run".

As expected, Comet Crommelin proved to be far from a spectacular object. Scientifically important observations were still obtained by European observers, especially by members of the astrometry, infrared, large-scale phenomena, spectroscopy, and radio nets.

Details of these observations were discussed at the general IHW meeting in Prague, June 20-22, 1984, and published in later IHW Newsletters. A suggestion was made to present the scientific results of the Comet Crommelin observations in a special session of a major astronomical meeting, such as the DPS meeting in October, 1984.

During the discussions, it was apparent that communication, especially between observers at different observatories, should be improved. A list of observers at the major observatories during critical time periods would be very useful, and would ensure more rapid communication.

It was again realized that the FITS format, as discussed in earlier IHW Newsletters, was not as widely used by different observers as was hoped. A more general use of this format should be encouraged.

Finally, ideas were exchanged on how to coordinate Comet Giacobini-Zinner observations, in particular to support the ICE mission, and to coordinate them with Comet Halley observations.

Th. Encrenaz

THE INTER-AGENCY CONSULTATIVE GROUP (IACG)

R. Reinhard
Space Science Department of ESA
ESTEC, Noordwijk, The Netherlands

Four space agencies - the Intercosmos of the USSR Academy of Sciences, the Japanese Institute of Space and Astronautical Science (ISAS), NASA, and ESA - are presently working on space missions to Halley's Comet (Table 1). Intercosmos will launch the Vega-1 and 2 spacecraft, ISAS will launch the Planet-A and MS-T5 spacecraft, and ESA will launch the Giotto spacecraft. NASA has already dispatched its ICE (formerly ISEE-3) spacecraft towards Comet Giacobini-Zinner, and thereafter to Halley's Comet.

TABLE 1

Key Data on Missions to Halley's Comet

Agency	Project	Launch	Flyby date	Flyby distance
ESA	Giotto	July 1985	13 March 1986	500 km
Intercosmos	Vega-1	December 1984	6 March 1986	10000 km
	Vega-2	December 1984	9 March 1986	3000-10000 km
ISAS	MS-T5	January 1985	March 1986	0.1 AU
	Planet-A	August 1985	8 March 1986	200,000 km
NASA	ICE	22 December 1983*	28 March 1986	0.21 AU

* Lunar swingby maneuver to inject ICE (formerly ISEE-3) into a heliocentric trajectory to Comet Giacobini-Zinner (flyby on 11 September 1985, 10000 km on the anti-sunward side)

Realising that many aspects of mission planning, spacecraft and experiment design, and data evaluation are common to all missions and that the overall scientific return could be increased through cooperation, the four agencies agreed in 1981 to form the Inter-Agency Consultative Group. The IACG has the task of informally coordinating all matters related to the space missions to Halley's Comet, while all ground-based Halley observations are being coordinated by the IHW.

The first meeting of the IACG took place on 13-15 September 1981 in Padua, Italy. At this meeting numerous details on the various space missions were exchanged for the first time and the general principles of cooperation were established. Three working groups were formed in which many of the problems common to all space missions to Halley's Comet are discussed, resulting in recommendations to the flight projects or actions to carry out specific tasks. The three working groups are:

- the Halley Environment Working Group (WG-1)
- the Plasma Science Working Group (WG-2)

- the Spacecraft Navigation and Mission Optimization Working Group (WG-3)

These working groups each have between 10 and 20 members from the various flight projects, and they meet twice per year on average. One of their meetings is held just prior to an IACG meeting which allows the WG chairmen to report back to the IACG and obtain an immediate reaction.

The IACG meets annually, with the task of organizing the meeting, and consequently the meeting place, rotating within the four agencies. The second IACG meeting took place in Dobogoko, Hungary on 21-22 November 1982 at the invitation of Intercosmos, and the third meeting in Kagoshima, Japan on 18-19 December 1983 at the invitation of ISAS (Table 2). The next three meetings are already scheduled to take place in Tallinn, USSR (Oct/Nov 84), near Washington, D. C. (mid Sept 85), and again in Padua, Italy (early Nov 86).

TABLE 2

Delegation Members at the Third IACG Meeting in Kagoshima, Japan

Chairman: M. Oda, ISAS	<u>ESA Delegation</u>	<u>NASA Delegation</u>
Sec.: R. Reinhard, ESA	R.M. Bonnet, Del. Head	G.A. Briggs, Del. Head
	D.C. Dale	J.A. Dunne
	J.A. Jensen	C.T. Force
<u>Intercosmos Delegation</u>	V. Manno	J.W. Head
R.Z. Sagdeev, Del. Head	R. Reinhard	J.F. Jordan
G.S. Balayan		D.P. Rausch
A.A. Galeev	<u>ISAS Delegation</u>	F. Scarf
L.I. Gussev	K. Hirao, Del. Head	L.L. Wilkening
B.A. Stroganov	Y. Kozai	
A.A. Sukhanov	T. Nomura	<u>IHW Representatives</u>
A.I. Tsarev	H. Oya	R.L. Newburn
	M. Shimizu	J. Rahe
	H. Yamamoto	D.K. Yeomans

A major outcome of the third IACG meeting was the re-organization of WG-3 into the Pathfinder Implementation Group as a direct consequence of the ESA/USSR Academy of Sciences Agreement on the mutual exchange of information needed for navigation. In short, the 'Pathfinder Concept' allows Giotto to be targeted much more precisely than would be possible if the Giotto navigation were based on ground-based observations alone. This is achieved by the timely transmission of data (Vega orbit and attitude information, camera pointing angles) from the Vega to the Giotto Project (Vega 1 & 2 encounter the comet a few days earlier than Giotto). Details of the pathfinder concept and some activities of WG-1 and WG-2 are described in ESA Bulletin, no. 38, May 1984, pp. 90-98.

Also, at the Kagoshima meeting of the IACG, the two co-leaders of the IHW who participate regularly in IACG meetings presented a proposal (see below) to archive all calibrated Halley space flight data in the Halley Archive. The four agencies accepted this proposal and will submit data pool tapes to the IHW no later than 2 years after the encounters.

Since the IACG was formed 2 1/2 years ago, it has demonstrated an ever growing usefulness for the various flight projects as a focal point for exchange of information, discussion of common problems, and mutual support to enhance

the overall scientific return of the space missions to Halley's Comet. The IACG and its counterpart on the ground, the IHW, form the cornerstones of a global effort to explore Halley's Comet as completely as possible during its present apparition.

Proposal by the IHW to the IACG

1. All calibrated data acquired on Halley's Comet during its 1986 apparition (1982-1988), whether from the ground, the air, or space, shall be included in "The Halley Archive" to be produced by the International Halley Watch.

2.a. Raw or uncalibrated data shall be included in "The Halley Archive" only when the editor determines that no comparable calibrated data is available and that the raw or uncalibrated data is of scientific significance.

b. Graphical displays in the Halley Archive of data from two or more sources selected by the editor shall be encouraged, but any interpretations of the data by authors or the editor will be reserved for publication elsewhere.

3.a. All rights of publication or use of Halley data normally shall remain with the investigators for a period of two years after acquisition unless the investigators specifically agree in writing to their earlier release or publish them in the open literature before that date.

b. The preservation of rights in part a. of this paragraph shall not preclude the use of Halley data from any source by the flight projects for the purpose of improving the scientific return of their missions.

4.a. A temporary data archive has been created in computers in Pasadena, CA, USA, and Bamberg, FRG. Additional archiving computers shall be established at a maximum of three additional sites to be selected by majority agreement of the IACG.

b. All archiving computers shall be maintained with equivalent data content by means of exchange of data tapes at least once per month starting Jan. 1, 1985, and continuing until Feb. 1, 1989.

c. Existing archiving computers are storing all data in the FITS (Flexible Image Transport System) format endorsed by the International Astronomical Union. If other formats are selected for other computers, complete data shall be provided in English to all archiving centers to allow reading of the format selected. Test tapes of the format selected shall be exchanged at least three months before the first exchange of actual data.

5.a. A permanent archive shall be produced during 1989 by the International Halley Watch for free distribution to all investigators contributing to it. Additional copies shall be available for purchase.

b. The primary form of the permanent archive shall be a digital tape or digital disc version with complete printed instruction in English for reading it.

c. The secondary form of the permanent archive shall be a set of printed books in English. Imaging data will be presented as photographic prints and may be representative rather than comprehensive. Permission shall be given to parties recognized by the IHW or the IACG to translate the archive into any language and to print and distribute the translation.

d. The temporary data archives provided for in paragraph 4 may be maintained indefinitely at the discretion of the owners and users as a third form of permanent archive. After the temporary archives are completed with the transmission of the final exchange tapes on Feb. 1, 1989, these data also may be freely copied for use in other computers.

PROSPECTS FOR AIRBORNE OBSERVATIONS OF COMET HALLEY

Allan Meyer
Kuiper Airborne Observatory
Ames Research Center
M/S 2118-1
Moffett Field, CA 94035
USA

Using the ephemeris published in the Comet Halley Handbook, I have calculated a series of trial flight plans for observing Comet Halley. For the Kuiper Airborne Observatory, the constraints are the 35° lower elevation limit of the telescope, the ability to find and guide on the comet in twilight, and the usual 7.5-hour flight duration. I have not considered here the possibility of observing the tail when the head is below the elevation limit. Flight plans were calculated with dead legs to and from the comet observing leg, and a 40-knot wind from the west.

From November to mid-December 1985, Comet Halley will pass through opposition, the total magnitude (m_1) is predicted to rise from 10 to 8, and the minimum earth-comet distance will be 0.62 AU. An observing leg would be limited to about 3 1/2 hours by the flight duration limit. On December 21, 1985, $m_1 = 6.1$, and an observing leg 200 minutes long will be possible. As shown in Figure 1, the maximum observing time possible will drop rapidly after that date as the comet approaches the Sun. There is no benefit from changing latitude. In fact, Hawaii-based flights in late December would have about 10% less observing time. The advantage in flying at more northerly latitudes is provided by the more westerly aircraft heading, which acts to slightly delay the setting of the comet. On January 5, 1986, $m_1 = 5.7$, $\Delta = 1.2$ AU, and an observing leg would be only of about 40 minutes duration. After January 10, 1986, Comet Halley is not observable with the KAO, and it will not become observable again until about March 10, a month after perihelion, and then only for flights originating in Hawaii or farther south. By then the comet will be below -20° declination and will reach declination -47°.5 on April 10, 1986. In early April it will be nearest the earth at 0.42 AU and the predicted total

magnitude will be 4.0 or brighter.

During March and April, Hawaii-based flights would have observing legs to the south, some within 500 miles of the equator. Equatorial high tropopause and high clouds may jeopardize the value of Hawaii as a base for this time period. As Figure 1 shows, much longer observing legs would be provided by flights originating in Sydney, Australia, and a limit of about 4 hours observing would be reached in mid-April. Hawaii-based flights would reach that limit about two weeks later, except that the observing time possible at closest approach will be only about 2 hours 40 minutes due to the extreme southern declination of the comet at that time. During April, Comet Halley will gradually become accessible to local flights out of Ames, but only by flying long dead legs to and from an observing leg in tropical latitudes.

A discussion of observing prospects with the Lear Jet Observatory will be presented in a future Newsletter.

> "Since the dust tail represents a relatively thin layer . . . extending in a comet's orbit plane . . . its appearance is affected by both the level of dust production and the projection conditions for the observer. . . . the projected width of the tail in the sky is strongly dependent on the Earth's cometocentric latitude. . . . The most favorable projection conditions for the tail will occur in early April, as the Earth's cometocentric latitude reaches a peak of 28° on April 7. . . ."

Z. Sekanina, in Comet Halley Handbook (2nd Edition)

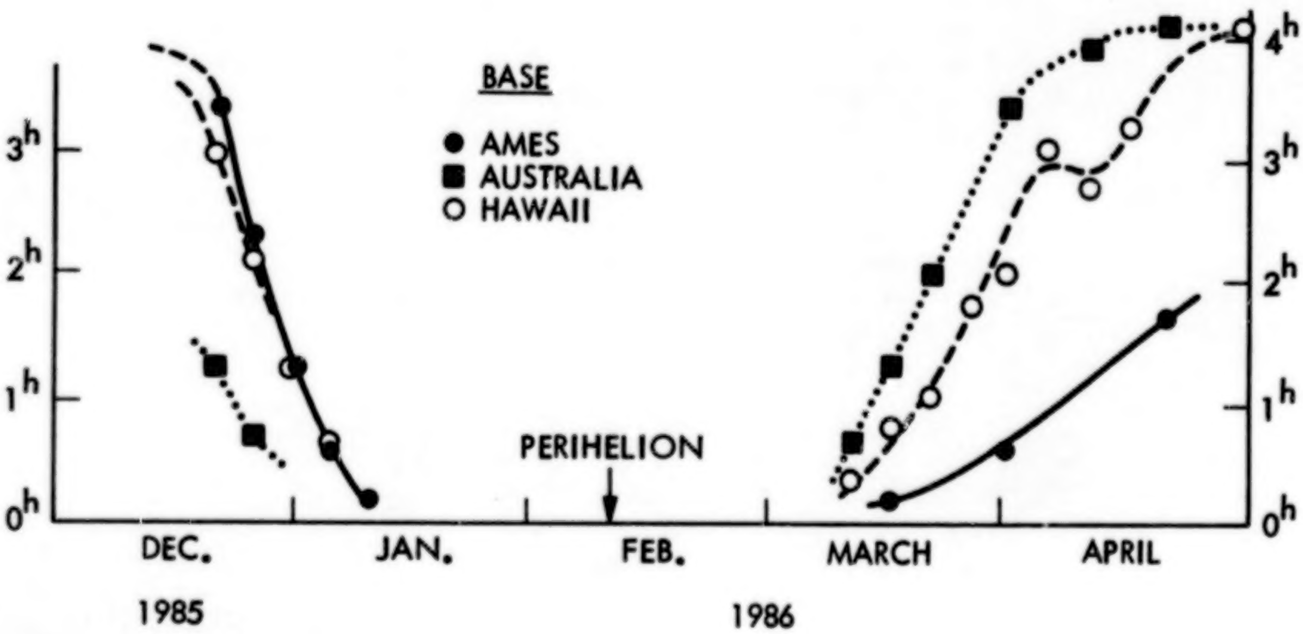


Figure 1. Maximum observing leg duration for Comet Halley from K.A.O.

USE OF THE ANGLO-AUSTRALIAN TELESCOPE FOR COMET HALLEY

David Allen
Anglo-Australian Observatory
P. O. Box 296
Epping, N. S. W. 2121
AUSTRALIA

Applications

Observing time on the 3.9 m AAT is shared equally between the Australian and UK communities, and separate allocation committees exist for the two. The Australian committee, ATAC, is based at the Anglo-Australian Observatory, PO Box 296, Epping, NSW 2121, Australia. The UK committee, PATT, can be reached at Science and Engineering Research Council, PO Box 18, Swindon, SN2 1ET, England. In general, UK applicants apply to PATT, Australians to ATAC, whilst other nationals may apply to either committee. ATAC allocations (subject to change) are:

Allocation period	ATAC deadline	PATT deadline
Mar, Apr, May	Nov 30	Nov 7
Jun, Jul, Aug	Feb 28/29	Nov 7
Sep, Oct, Nov	May 31	May 7
Dec, Jan, Feb	Aug 31	May 7

All applications should be made on the standard forms of one or other committee. These are available from the committees in question.

During the months of March and April 1986 it is anticipated that the AAT may be asked to play a major international role in Halley observations. Special plans are being evolved to handle applications both from within and outside the UK and Australia for this two-month period. Observers who wish to study Halley at other times should make applications in the usual way to ATAC or PATT.

Although applications to ATAC or PATT can be accepted as late as 1 November 1985 for the two months of particular interest, it is strongly recommended that they be submitted by 1 November 1984. Applications may be made to either committee; each committee will communicate to the other the applications it receives and its deliberations thereon in order that unnecessary duplication can be avoided.

The principal advantage of an early application is that it gives each committee time to seek expert advice on its importance, and if necessary to discuss it with the applicant(s) where clarification is required. The firm allocations for March and April 1986 will be made by the two committees at their normal meetings held early in January 1986.

When composing their scientific justifications, applicants should recall that the committees are not convened purely to allocate Halley observations, but are constituted to handle applications covering a great range of astronomical topics.

There is no guarantee that time will be made available for observations of Halley's comet even during March and April 1986. However, the uniqueness of the opportunities afforded will be borne in mind by the allocation committees. Notwithstanding the fact that the IHW has dedicated Halley Watch days around new moon, applicants should recognize that they may be granted time at bright of moon. The observations that can be made with the small field of the AAT will usually be of the brighter regions, so that dark time may not technically be necessary. Demand for dark time is usually so great that committees look critically for programs which may use brighter skies than requested. All applications to study Halley's comet should give a thorough scientific case if dark skies are needed.

Instrumentation

Details of AAT instruments, and of the telescope and its performance, can be found in various handbooks available in many institution libraries. Copies may be purchased from AAO (address as above). The following list summarises the instruments currently operated at the telescope, and those expected to be available by 1986.

Optical

Cassegrain auxiliary focus photometry using S-20 or GaAs photocathodes and standard UBVRI etc. filters. The IHW filter set is not resident at AAO. High-speed photometry software is available. The photometer can be used on the same night as another Cassegrain instrument.

CCD at prime focus where the image scale is 16.2 arcsec/mm. Currently available is a thinned RCA chip with 30-micron pixels. By 1986 it is anticipated that a GEC chip will also be available, with much lower readout noise, somewhat lower quantum efficiency, poorer blue response than RCA chips, and no fringing.

A Cassegrain (f/8) spectrograph (the RGO spectrograph) offers a range of dispersions from 3 to 110 A/mm. This range is achieved by the use of two cameras, of focal lengths 25 and 82 cm. The detector is usually the photon counting IPCS (resolution about 40 microns in the dispersion direction), but a CCD can be used. The maximum usable slit length is 4 arcmin.

Additionally, the high-throughput spectrograph FORS shares the slit of the RGO spectrograph but is a fixed-format, collimatorless design feeding a GEC CCD at 10A/pixel, covering the range 5000-10000 A. With the use of a dichroic, the blue may be observed on the IPCS while the red enters FORS.

Infrared

The f/15 IRPS offers the standard broad-band filters (JHKL'M) suited to its InSb detector, together with a circular variable filter (CVF) giving spectroscopic options in the H, K and L windows at resolutions of 100. Images through any filter or CVF position can be made by scanning the telescope under software control. The maximum aperture size is 14 arcsec.

It is anticipated that by 1986 a grating spectrometer will be available for the same wavelength range offering resolution up to 2000. The use of etalons may be possible, raising the resolution to nearly 50,000.

Polarization measurements may also be possible by 1986; the wavelengths are yet to be defined.

Access to the Telescope

The AAT stands on Siding Spring Mountain, inland New South Wales, about 500 km from Sydney. Presently the nearby town of Coonabarabran is serviced three times a week by Air New South Wales.

Inquiries

The author is the local IHW representative and can be contacted at the address above.

LIKELY OBSERVING CONDITIONS IN AUSTRALIA

David Allen
Anglo-Australian Observatory
P. O. Box 296
Epping, N. S. W. 2121
AUSTRALIA

Because Halley's comet will be at its best after perihelion, when it will lie at southern declinations, boreal inhabitants may prefer to journey south of the equator for a good view. Australia is one obvious target. Here are a few notes on the climate and conditions likely to be encountered.

Entry into Australia will normally be made via one of the cities -- Sydney, Melbourne or Perth in particular. Like cities everywhere, these places generate considerable light pollution together with some smoke and smog. They should certainly be avoided as sites for Halley watching. The cities cling to the periphery of this big continent, and this is also the region of highest rainfall and cloud cover. Although there will undoubtedly be some good observing sites along the littoral strip, it would be better to venture inland. The major optical observatories, Siding Spring and Mt. Stromlo, both lie about 200 km from the coast.

Going too far inland, particularly in the northern half of the continent, certainly avoids the lights, but can land the observer in poor transparency because of wind-blown dust. Inland mining towns should be avoided too. In fact, dust or the smoke from bush fires are a potential hazard anywhere on the continent if there has been a particularly dry summer. Mountain sites rise above the dust. They also have much better seeing than is encountered on the plains below, but they do attract some orographic cloud. Since seeing is not critical to most observers of Halley's comet, the moister plains should probably be preferred, perhaps with access to a mountain if no cloud interferes. Almost anywhere in eastern New South Wales and Victoria, or the west of Western Australia would have good potential. Further inland most roads are unpaved and dust could be a major probem.

There are a number of interesting vacation spots in Australia which might be combined with a comet trip. Those who have never visited the country will likely find most distinctive and interesting the wildlife (available almost anywhere), the Great Barrier Reef, and the Red Center. The latter refers to a

number of scenic and Aboriginal attractions within a day or two's drive of Alice Springs, most notably Ayers Rock. Tasmania is also a very attractive vacation spot, but offers scenery more typical of other parts of the world, together with a less reliable climate.

Those of an astronomical bent will be particularly interested in the Henbury meteorite craters and Gosse's Bluff, both near Alice Springs, in the display of meteorites in the Perth museum, and in the observatories of the eastern region. The latter are: Tidbinbilla satellite tracking station near Canberra, Mt. Stromlo Observatory near Canberra, the 64 m radio telescope near Parkes, and Siding Spring Observatory near Coonabarabran. Easy one-day drives link Canberra to Parkes and Parkes to Coonabarabran, all on paved roads. Tidbinbilla and Parkes share the responsibility of receiving the Giotto satellite transmissions. Siding Spring Observatory is on the fringe of the particularly beautiful Warrumbungle National Park. The spur roads to Siding Spring and Mt. Stromlo Observatories are not open to the public at night. However, the public road leading from Coonabarabran to the Warrumbungle National Park rises sufficiently to leave behind most wind-borne dust. An alternative site in this region is Mt. Canobolas, outside Orange and an hour's drive from Parkes. The lights of the township of Orange would be only a slight hindrance from there. Attractive mountain sites include Mt. Kaputar, outside Narrabri to the north of Coonabarabran, and Mt. Buffalo in Victoria. Both are national parks with campsites. At altitude the nights may be quite cool in April.

The Australian Bureau of Meteorology kindly made available cloud-cover statistics for three areas. Only daylight records are kept in the more remote regions. I preferred the 9 a.m. data to those later in the day, since cumulus clouds frequently build up during the afternoon across much of Australia, only to disperse again at dusk. Three sites were chosen: Pine Islet lies at the southern end of the Great Barrier Reef, Dubbo (lying between Parkes and Coonabarabran) is representative of the inland plains of NSW, and Ayers Rock is representative of the Center.

	# years averaged	Dec	Jan	Feb	Mar	Apr	May
Ayers Rock	15-16	3	2	3	2	2	3
Dubbo	76-77	2	2	3	2	2	3
Pine Islet	43-44	4	5	5	5	4	4

These statistics clearly show the coastal station to be twice as cloudy as inland sites. There is no difference in cloud cover between Dubbo and Ayers Rock, but the latter would certainly be dustier (all roads there are unpaved; dust in the air at sunset enhances the Rock's famous red hue). Since cloud patches typically last 1-3 days, a four-five day visit (preferably around new moon on 9 April) would virtually guarantee a good view of the comet.

STATUS REPORT ON THE PLANET-A PROJECT

Kunio Hirao, Hiroki Matsuo, and Kuninori Uesugi
Institute of Space and Astronautical Science
4-6-1 Komaba, Meguru-ku
Tokyo 153
JAPAN

Abstract

Planet-A, Japan's first interplanetary flight project, has come to the final phase of its implementation. MS-T5, which is the test spacecraft, has completed assembly and now some pre-flight tests are being carried out. MS-T5 will be launched from Kagoshima Space Center in early January, 1985.

As for the second and main spacecraft to explore Halley's Comet, Planet-A, every component of the spacecraft is being fit-checked. This spacecraft will also be launched from Kagoshima Space Center in August 1985, and will encounter Halley's Comet on March 8, 1986.

The newly developed launch vehicle, M-3SII rocket, is now almost ready for flight. The construction of the Deep Space Center with 64 m dish antenna at Usuda-cho, Nagano Prefecture, is also almost completed and its functional tests for tracking and data acquisition will soon be conducted. Many kinds of software necessary to operate and control both spacecraft have been developed and the simulation tests and check-out are being carried out.

Introduction

The Institute of Space and Astronautical Science (ISAS) is now making every endeavor for the implementation of the Planet-A project, which aims to explore Halley's Comet as Japan's first interplanetary flight. This mission consists of two spacecraft, MS-T5 and Planet-A. The first spacecraft, MS-T5, has completed assembly and now some pre-flight tests are being carried out. Although MS-T5 is basically a test spacecraft for the verification of launch vehicle capability, of new technology which is adopted in the spacecraft itself, and of the deep space communication system, this mission is also intended to participate in the exploration of Halley's Comet with two solar wind plasma and one magnetic field experiment on board. Since the solar wind is known to influence strongly the structure of the coma and the tail of a comet, these experiments are expected to provide a significant contribution to the international cooperative Halley's Comet exploration program.

Planet-A, the second and main spacecraft to explore Halley's Comet, will carry two scientific instruments on board. They are a vacuum ultra-violet camera to take images of the hydrogen corona surrounding the coma and a plasma energy spectrum analyzer to measure the three-dimensional distribution of ions and electrons of the solar wind as well as those emitted from the corona of the comet.

Mission Description

Heliocentric Orbit

Planet-A will depart the Earth in mid-August 1985, and will encounter Halley's Comet on 8 March 1986, when the comet will be near its descending node. The trajectory of Planet-A will make almost 3/4s of a revolution around the Sun. Figure 1 shows the heliocentric geometry of the mission, and Table 1 lists the relevant parameters of the nominal trajectory. A launch window of 20 days, until the beginning of September, is available during which the launching with C_3 below 9.0 km^2/sec^2 is possible. As seen in Table 1, we consider 14 August 1985 to be the nominal launch date of Planet-A.

Since the primary scientific objective of Planet-A is to take continuous images of the hydrogen corona of the comet, a close encounter is not necessarily required. A closest approach distance of around 200,000 km with sunward passage is now planned.

Preceding the Planet-A spacecraft, a test spacecraft, MS-T5, will be launched into interplanetary space in early January 1985. It will make one and a half revolutions around the sun and will reach the neighborhood of Planet-A when it encounters the comet, thus making collaborative observations possible. A miss distance of several million km between MS-T5 and the comet is expected. The heliocentric geometry and orbital parameters of MS-T5 are also shown in Figure 1 and Table 1. The nominal launch date of MS-T5 is 5 Jan. 1985 (JST).

TABLE 1
Nominal Orbital Parameters
of Planet-A and MS-T5

	PLANET-A	MS-T5
Launch Date (UT)	August 14, 1985	January 4, 1985
Arrival Date	March 8, 1986	March 8, 1986
a (km)	127,172,358	135,640,150
e	0.193	0.115
i (deg)	0.737	1.508
Ω (deg)	140.92	284.27
ω (deg)	147.39	245.59
r	March 31, 1985	April 30, 1985
C_3 $(km/s)^2$	9.0	8.0

Launch Trajectory

Planet-A and MS-T5 will be launched easterly from Kagoshima Space Center (KSC), located in the southern part of Japan (31.25°N, 131.08°E). Direct injection without parking is employed in order to save the weight of the attitude control system required to reorient the kick stage on the parking orbit. That is, the spin-stabilized third stage and kick stage are serially fired near the apogee of the second stage trajectory.

This fact, with the constraint on the launch azimuth due to range safety aspects, leads to the limitation of the launch asymptote declination to be less than about -28° in order to keep the injection flight path angle reasonably low, and thus to avoid the gravity loss during the injection phase. The nominal

injection parameters of these spacecraft are listed in Table 2.

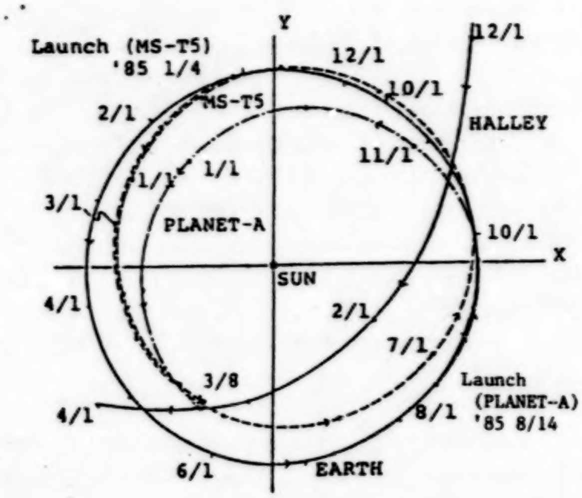


Figure 1. Heliocentric Orbit of Planet-A and MS-T5

TABLE 2

Injection Parameters of Planet-A and MS-T5

		PLANET-A	MS-T5
Launch Time	(UT)	0h07m Aug. 14, 1985	19h42m59s Jan. 4, 1985
Injection Altitude	(km)	250.0	250.0
Latitude of Injection Point	(deg)	30.90	30.92
Longitude of Injection Point	(deg)	138.00	138.00
Absolute Burnout Velocity	(km/s)	11.3740	11.3067
Flight Path Angle	(deg)	0.002	0.060
Azimuth Angle	(deg)	94.25	94.24

Spacecraft Operation Strategy

Two stations of ISAS, one at KSC with a 10 m antenna and the other at Usuda-cho (36.13°N, 138.37°E), Nagano-Pref., with a 64 m antenna are available for spacecraft operation. It is anticipated the Nasda Katsuura station and NASA/DSN will provide antenna angle data and ranging data, respectively, during the launch phase. A central spacecraft operation facility will be set up at ISAS, Tokyo and all downlink and uplink data will be handled here.

Immediately after the spacecraft injection, that is, the burn-out of the kick stage, the spacec-aft goes out of sight of the KSC station. During this invisible time, the attitude control system reduces the spin rate of the spacecraft from 2 rps to 30 rpm and then directs the spin axis normal to the sun-spacecraft line in order to make enough power available from the body-mounted solar array.

The spacecraft becomes visible again from KSC 5 hours after injection and the preliminary orbit determination will be carried out during this passage. At the second passage of the spacecraft over Japan, tracking, data acquisition, and commanding is changed from through KSC to through UDSC (Usuda Deep Space Center) which is remotely operated from ISAS, Tokyo. During this passage the spin axis of the spacecraft is oriented to the direction which makes the high gain antenna atop the spacecraft point towards the Earth.

After the first 4 or 5 days of accurate ranging and orbit determination, a midcourse correction maneuver will be carried out. Since at most only 100 m/s correction capability is available to the spacecraft, it is anticipated that the ΔV requirement due to injection error (nominal 1σ values of the injection velocity dispersion are 30 m/s in magnitude and 0.5° in direction) may exceed this capability. If ΔV stays within the capability, a second midcourse maneuver will be carried out.

After the midcourse maneuver, the spacecraft takes its cruising attitude with its spin axis normal to the ecliptic plane. An attitude maintenance maneuver, in order to withstand solar radiation pressure, will be conducted once every 20 days. During the comet observation phase, which extends 10 days before and after the closest approach to the comet, the spin rate will be reduced to 0.2 rpm from the cruising 6.3 rpm by running up the momentum wheel. During this low spin rate phase, only the uplink communication is available and imaging data stored in a data recorder are transmitted to the earth after the spin rate returns to 6.3 rpm again.

Launch Vehicle

The launch vehicle which is used in the Planet-A project is the M-3SII rocket. The M-3SII is the newest version of the Mu launch vehicle family developed by ISAS. A cutaway view and its characteristic parameters are shown in Fig. 2 and Table 3, respectively. The rocket's total length is 27.8m, 1.65m in maximum diameter (excluding 2 SOB's), and launch weight is 62 tons. Almost all components and subsystems of the first M-3SII, which will carry the MS-T5 spacecraft into space, have been manufactured and solid propellant loading for each stage rocket motor is now being carried out.

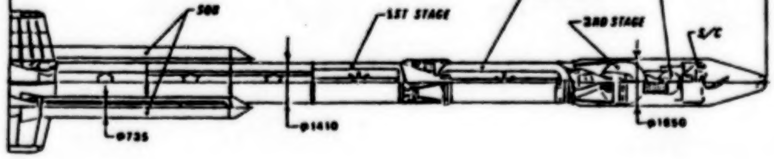


Figure 2. M-3SII Cutaway View

TABLE 3
M-3SII Specifications

SPECIFICATION	FIRST STAGE	SOB	SECOND STAGE	THIRD STAGE	KICK STAGE
Thrust (N)	1,120 (Sea Level)	299 (Sea Level)x2	522 (Vacuum)	133 (Vacuum)	32 (Vacuum)
Propellants	Solid	Solid	Solid	Solid	Solid
Specific Impulse (s)	236 (Sea Level)	236 (Sea Level)	289 (Vacuum)	295 (Vacuum)	287 (Vacuum)
Effective Firing Duration (s)	56	31	55	71	36
Propellant Weight (t)	27.1	4.02 x 2	10.4	3.30	0.42
Stage Weight (t)	34.9	4.98 x 2	13.0	3.60	0.47
Guidance	Radio-Inertial Guidance				
Maximum Diameter (m)	1.65				
Total Length (m)	27.8				
Launch Weight (t)	62.0				

Spacecraft Description

The Planet-A spacecraft weighs about 136 kg and basically it has a cylindrical shape which is 1.4 m in diameter and 0.7 m in height with a high gain mechanically despun antenna atop. Medium and low gain antennas are attached to the bottom. The power required by the spacecraft is generated with body-mounted solar arrays. Figure 3 shows a cutaway illustration of Planet-A and Figure 4 depicts a system block diagram. Table 4 lists the Planet-A spacecraft weight breakdown.

The MS-T5 spacecraft is almost identical with the Planet-A spacecraft except for the scientific instruments and is heavier by about 2 kg than Planet-A.

Communication Subsystem

The communication subsystem consists of telemetry, command, and ranging subsystems with S-band transponder and antenna subsystems. It operates on S-band frequencies which are compatible with NASA's deep space frequencies. A downlink data transmission rate of 2,048 bps without coding or 64 bps with coding is available depending on communication distance. Onboard magnetic bubble memory with 1Mbit capacity can reproduce the stored data at the same rates. For the uplink, command signals are sent with a bit rate of 16bps. The transmitters put out either 0.07 or 5 watts of power on command. The antenna subsystem consists of high, medium and low gain antennas. The high gain antenna is an offset-parabolic dish of 80 cm in diameter and is mechanically despun.

TABLE 4

Planet-A Weight Breakdown

Power Subsystem	
Solar Cell Panel	12.5
Battery	2.3
Converter	2.5
Power Control Unit	2.0
Ignition Power Unit	0.2
Circuit Sensor	0.4
Sub-Total	19.9

Communication & Antennas Subsystem	
Low Gain Antenna	0.2
Medium Gain Antenna	1.3
High Gain Antenna	3.7
Transmitter & Receiver	6.2
Rotary Joint	0.9
Despun Motor	5.3
Sub-Total	17.6

Telemetry & Command Subsystem	
Data Processing Unit	3.6
Command Decoder	1.4
Data Recorder	2.3
Housekeeping	2.0
Sequence Timer	1.5
Sub-Total	10.8

Control Subsystem	
Momentum Wheel	7.4
Wheel Driver	1.1
Control Circuits	4.3
Sun Sensors	0.9
Star Scanner	3.7
Nutation Damper	0.5
Propulsion System	20.2
(propellant)	(10.0)
	38.1

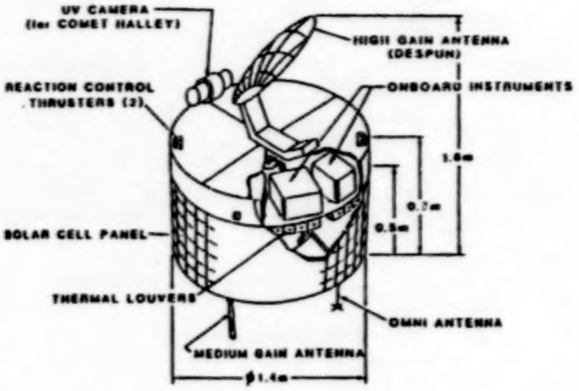
Structure & Thermal Control Subsystem	
Structure	19.0
Thermal Louvers	2.3
Blankets etc.	4.8
Sub-Total	26.1

Integration	
Bolts etc.	6.2
Circuits	4.9
Sub-Total	11.1

Scientific Instruments	12.6
Total Weight (kg)	136.2

Attitude and Orbit Control Subsystem

The attitude and orbit control subsystem consists of a hydrazine gas jet subsystem, bias momentum wheel, nutation damper, attitude sensors and control electronics. The hydrazine gas jet subsystem with six body-fixed 3 N thrusters provides orbit correction, spin axis precession, and spin-up and -down capabilities. Both N_2 pressurant gas and 10 kg N_2H_4 propellant are stored in the same tanks and a blow down system is adopted. The nominal stored angular momentum of the wheel is 20 Nms at 2,000 rpm. During the imaging operation, the wheel absorbs the angular momentum of the main body and stabilizes the spacecraft motion. The spin-type sun sensor provides the sun-line to spin axis angle and a spin-synchronized pulse train which is used to control the solar shutter of the UV camera and to determine the timing of imaging and jet thrusting for attitude control. The star scanner is a passive scan type with two light sensitive silicon strips placed on the focal plane of the optical system. One element is nominally parallel to the spacecraft spin vector and the other inclined 20° with respect to the first. These light detector strips provide the calibrated star light incidence signals which can be used to determine the spacecraft attitude.



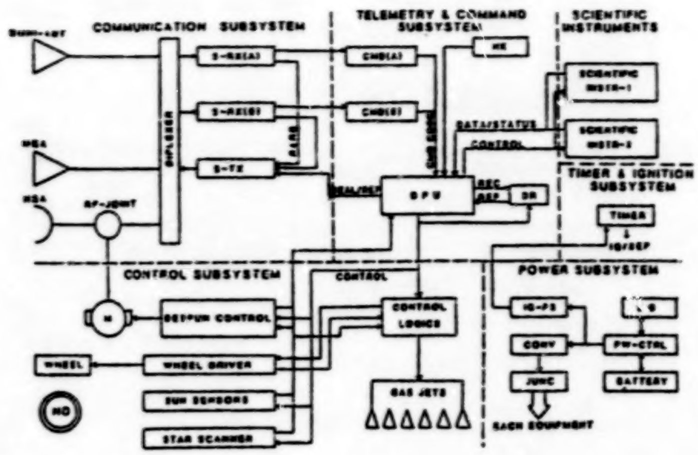


Figure 3. Planet-A Cutaway View

Figure 4. Planet-A System Block Diagram

Scientific Instruments

Planet-A carries two scientific instruments, that is, a vacuum ultraviolet camera and a solar wind particle analyzer. The camera takes pictures of the hydrogen coma of the comet with a field of view of 2.5° x 2.5°. A two dimensional CCD is used for the image detector. To avoid blur of the image due to the spin of the spacecraft, a special technique called spin-synchronized charge shift is employed on the CCD.

The solar wind particle analyzer measures the three-dimensional distribution of the solar wind plasma within ±30° to the ecliptic plane. The analyzer consists of two charged particle detectors for electrons and ions in the energy range from 30 eV up to 16 keV in 96 steps with exponential energy sweep.

Scientific measurements onboard MS-T5 are complementary to those of Planet-A. The first instrument is a plasma wave probe to detect the plasma wave instability at the local plasma frequency and electron harmonic wave emission in a frequency range from 70 Hz to 200 kHz. A short dipole antenna with length of 10 m tip to tip is used. As a second instrument, a Faraday cup device is used to measure solar wind ion flux and its bulk velocity and temperature. Sweep range of the retarding voltage is from 300 V to 1.7 kV. The third instrument is a ring core type fluxgate magnetometer to measure both macroscopic and microscopic structures of the interplanetary magnetic field. These measurements are quite useful to interpret the geometrical features of the comet.

Concluding Remarks

The first Japanese interplanetary flight project has come to the final phase of its implementation. Besides the scientific achievements, the technological experience through this mission along with the construction of the deep space station will open the way for succeeding domestic missions and international cooperations in this field.

SOLAR MAXIMUM MISSION OBSERVATIONS OF HALLEY'S COMET

K. J. Frost and B. E. Woodgate
Laboratory for Astronomy and Solar Physics
Goddard Space Flight Center
Greenbelt, MD 20771,
USA

L. L. House
High Altitude Observatory
National Center For Atmospheric Research
Boulder, CO 80302,
USA

Introduction

In April of 1984 the space shuttle successfully repaired, in orbit, the attitude control system and the coronagraph-polarimeter on the Solar Maximum Mission (SMM) observatory. After the repair the SMM will be returned to full operational status. Not only will the observatory renew its research program in solar flare physics, but it will also make unique observations of Halley's Comet from January through March of 1986. The instruments that will be used for this purpose will be the Ultraviolet Spectrometer-Polarimeter (UVSP) and the Coronograph-Polarimeter (C/P). Both instruments have many computer selectable and controllable observing modes. The other instruments in the SMM payload will be on and operating while the C/P and UVSP observe the comet. Although detectable emissions observed by these other instruments are unlikely, given the known comet physics and separation of SMM from the comet, the data can be used to establish measured upper limits and search for emission induced by events like sector boundary disconnections and solar flare phenomena such as blast wave or energetic particle beam encounters.

Preliminary observing plans for Halley's Comet are described below. After the repair and consultation with members of the International Halley Watch a final observing plan will be devised. The plan will then be converted into an operating plan for the SMM observatory and the participating instruments. The operations will include real time observing periods provided by the capabilities of the Tracking and Data Relay spacecraft. The real time periods may be used to assure optimum quality in each observation by enabling fine tuning of the exposure times, fields of view, and spacecraft pointing, among other things. A number of practice runs will be conducted prior to the observing period to assure a smooth and efficient collection of observations when the comet is available to SMM.

A detailed description of the SMM payload and spacecraft is contained in Bohlin et al. (1980).

Ultraviolet Spectrometer-Polarimeter Capabilities

UVSP is best used to provide ultraviolet coverage of the comet when it is within 50 degrees of the sun. This occurs through perihelion, from January 4 to March 11, 1986. In the range 15 to 50 degrees from the sun (θ), UVSP can view the comet in full sunlight. For θ from 15 to 6.6 degrees at perihelion, the

UVSP will use earth occultation to view the comet.

UV brightness estimates of Halley's Comet suggest that it will vary from a factor of 0.3 to 6 of the IUE measurement of Comet Bradfield. From these estimates UVSP should be able to do the following:

1. Make maps of OH to three arc seconds resolution and HI (Ly α) to 30 arc seconds resolution as a function of time.
2. Make spectra of OH (0.06 Å resolution) and HI (0.2 Å resolution) as a function of space and time.
3. Detect CI and OI close to perihelion.
4. Detect polarization of strong lines to check their fluorescence excitation.

Ionic species probably cannot be detected. Maps of the neutral species mentioned above will provide scale lengths as a function of distance from the sun and enable photochemical production and decay rates to be determined. Spectra will enable velocities of these atomic and molecular species to be found as the distance to the sun varies.

Brightness Estimates

Feldman et al. (1980) give for Comet Bradfield the following intensities:

Species	Wavelength (Å)	Brightness (Kilorayleighs)
HI (Ly α)	1216	160
OI	1304	0.33
CI	1657	0.55
OH (0,0)	3082	370

Feldman estimates Halley should be twice as bright as Bradfield at the same distance (R = 0.71 AU). Assuming brightness varies as $r^{-6.5}$, Halley brightness at r = 0.85 AU is 0.3 times the brightness listed in the table. At perihelion (r = 0.59 AU) the Halley brightnesses should be 6 times the values listed in the table.

Schedule

Dates (1986)	(AU)	Θ	Comments
Jan 4-28	0.91-0.65	50-15.5	SMM/UVSP observes in full sun
Jan 28-Feb 9	0.65-0.59	15.5-6.5	SMM/UVSP observes with earth occultation
Feb 9-Feb 16	0.59-0.60	7.6-15.9	SMM/UVSP observes with earth occultation
Feb 16-Mar 11	0.60-0.86	15.9-50	SMM/UVSP observes in full sun

UVSP Observing Modes and Count Rates

UVSP count rate, $C = L\ A_{eff,\lambda} A_s\ (\Delta\lambda_\sigma/\Delta\lambda)$ counts/sec, where

L	= source brightness in spectral line (ph $cm^{-2}\ s^{-1}\ arcsec^{-2}$)
$A_{eff,\lambda}$	= effective area of UVSP (cm^2)
A_s	= entrance slit area ($arcsec^2$)
$\Delta\lambda_\sigma$	= exit slit width (Å)
$\Delta\lambda$	= line width (Å)

UVSP background rate ~ 0.1 counts/sec. to detect lines so $C \geq 0.1$ c/s is needed. (For convenience, 1 kR = 0.37 photons $cm^{-2}\ s^{-1}$ from 10 $arcsec^2$.)

Using the brightnesses in the table, we find:

Mode 1: HI images, 30 x 30 arc sec resolution, 0.6 Å spectral width.

For $\Delta\lambda < 0.6$ Å, A_{eff} at 1216 Å = $10^{-3} cm^2$, C = 0.6 c/s.

In one orbit a 4 x 4 arc minute image could be obtained with an average of 30 counts per pixel. A larger spaced array to fit the HI cloud size could be built using spacecraft adjustments or UVSP Co-Alignment System adjustments.

Mode 2: OH, 3082 Å images, 3 x 3 arc sec resolution, 0.06 Å spectral width.

For $\Delta\lambda = 0.06$ Å, A_{eff} at 3082 Å $\sim 3 \times 10^{-2}$ cm^2, C = 0.4 c/s.

In one orbit, a 5 x 5 spaced array matched to the OH cloud size could be obtained with an average of 60 counts per pixel. If appropriate, a small image with 3 arc sec resolution could be made.

Mode 3: OH 3082 Å spectra, 1 x 180 arcsec slit, 0.06 Å spectral resolution.

For 50 arcsec cloud diameter and $\Delta\lambda = 0.06$ Å, C = 0.7 c/s.

Spectra may be taken to measure velocities with respect to the nucleus to 3 km/s in about 10 minutes. Five spatial slices could be obtained in one orbit.

Mode 4: Short wavelength spectra, 15 x 286 arcsec, 0.2 Å spectral resolution.

For 50 arcsec cloud diameter and $\Delta\lambda = 0.2$ Å, we obtain the following values at perihelion:

Species	λ (Å)	A_{eff} (cm^2)	L(kR)	C (c/s)
HI	1216	10^{-3}	960	0.6
CI	1657	10^{-1}	3.3	0.9
OI	1304	10^{-2}	2.0	0.05

Coronagraph/Polarimeter Observations of Halley's Comet

The repair of the Coronagraph/Polarimeter on the SMM satellite would permit important and unique observations to be made on Halley's Comet. The technique as proven by ATM observations of Comet Kohoutek is significantly enhanced by the

improved capabilities of the C/P over Skylab's Apollo Telescope Mount (ATM) instrument. The C/P instrument with its multicolor photo-polarimetry imaging capabilities will add significant data to the study of comets.

Below are outlined some of the capabilitites of the C/P instrument relevant to the observation of Halley's Comet.

Field of View and Spatial Resolution

The field of view of the coronagraph is 1°.6 by 1°.6. The SEC vidicon detector images contain 896 x 896 pixels, each with 8 bits of intensity information.

The coronagraph can operate safely outside a cone of about 4.5 degrees from sun center. It appears that the comet comes within a minimum of 6 degrees from the sun. Very roughly speaking, in mid January when the comet is about 30 degrees from the sun, extended periods of observation are possible with SMM without undue concern for power requirements. Peak power for C/P is around 50 watts and average background power is about 40 watts. At angles greater than 30 degrees from the sun, short periods of observation with further off-pointing may be feasible. Assuming availability of TDRSS (Tracking and Data Relay Satellite System), real-time command and data acquisition would permit C/P to locate and make initial observations of the comet.

Temporal Resolution

For calibration purposes the C/P has observed 6th magnitude stars using the broad-band green filter with an exposure time of 6 seconds. The observations were made through the corona as background. The exposure for extended observations of the comet tail can be integrated for a significant period. For example C/P has made observations of the coronal green line integrating for 20 minutes with no noticeable effect from detector or electronic noise.

In contrast to ATM (with its longest exposure of 27 sec), the C/P (with its integrated exposure capabilities) would be invaluable in bringing out details of the comet. Exposure times can range upon command from as short as 2 seconds to as long as an hour.

Filter Capability

Table 1 gives the properties of the 5 filters in the filter wheel. The 6th filter is for the coronal green line (5303 Å) and will likely not be of interest in the comet observations. Obviously, multicolor observations are easily accomplished. This in combination with the polaroids gives information about the dust component. Images taken through the H-alpha filter may address the problem of the hydrogen cloud surrounding some comets. In combination with any Lyman-alpha data, perhaps a reasonable attack on the hydrogen problem could be made.

Polarimetry

Three polaroids at increments of 60 degrees permit complete determination of the linear polarization Stokes vector in combination with any filter.

TABLE 1

Summary of Coronagraph/Polarimeter Characteristics

Field of View	$6R_0 \times 6R_0$ Quadrant
Occulting Disk	$1.5R_0$
Spatial Resolution	
High	$(892)^2 \times 8$ pixels, 10 arc seconds
Low	$(448)^2 \times 8$ pixels, 20 arc seconds
Temporal Resolution	1.5 - 60 min (200 - 250 images/24 hrs.)
Filters	Wavelength (Å ± FWHM)
Wideband	4785 ± 340
Blue	4628 ± 160
Green	5171 ± 160
Red	6200 ± 220
Hα	6622 ± 80
Fe XIV	5303 ± 5.5 (Tunable 20 Å)
Polaroids	3 Linear, $\Delta\theta = 60°$
Stray Light	3×10^{-10} disk center brightness
Detector	Meshless SEC Vidicon
Data Recording	4.5×10^8 Bits
Control	On Board Computer
	Flexible Software - Real Time Observing
Pointing	Independent Gimbal ± 32 Arc Min

Status

On November 16, 1983, J. C. Brandt proposed to the SMM Investigators Working Group (IWG) carrying out a program of Halley observations during the period January to March 1986. The basic ideas were favorably received and all Investigators were willing to commit the observing time. A formal statement is expected after the IWG's mid-February 1984 meeting. Questions of resources remain to be resolved.

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APIAN'S WOODCUT AND HALLEY'S COMET

David W. Hughes
Department of Physics
The University
Sheffield S3 7RH
ENGLAND

Rummaging recently through some of the past sightings of Halley's Comet I realized much to my chagrin that the beautiful Apian Woodcut (see figure 1) was not of our comet at all. So figure 4 of (Brandt et al, 1981) and figure 9 of my paper (Hughes, 1984) are incorrectly labelled.

The comet drawn in figure 1 is, however, famous. It has a tail which is clearly pointing in the anti-solar direction and this figure together with figures in another of Apian's books Astronomicum Caesareum (1540) obviously made a great impression because he is generally credited as being the first European discoverer of this fact. Unfortunately, Girolamo Fracastoro drew attention to this characteristic in his earlier book Homocentrica (1538) and both had been pipped at the post by the Chinese who had made a similar deduction about AD 800.

Figure 1 reproduces the first page of a short report of the observations of a new comet that had appeared during the "wine" month (October) and "winter" month (November) of the year 1532. The ecliptic is clearly shown with the constellations Virgo, Libra and Scorpius going from right to left. The stars at the top of the figure (from right to left) are Regulus (alpha Leonis), Arcturus (alpha Bootes) and Vega (alpha Lyrae). The comet is moving from right to left also, the first image corresponding to its position on 2 October 1532 and the last to 8 November 1532, these corresponding to the arc dates used by Brian G. Marsden in his "Catalogue of Cometary Orbits". Comet 1532 passed perihelion on 1532 October 18.832 and was a long period comet. Comet Halley had appeared in an adjacent region of the sky in August of 1531. Its positions between the 13th and 18th of that month are given in figure 2, perihelion passage occurring about 1531 August 26.2. Halley's Comet was first recorded, at that apparition, on 5 August, in the region of Zeta and Gamma Geminorum. It disappeared from sight 34 days later by which time it was near Spica. Periodic comets are in general less bright than long period ones, having been in the inner solar system longer and having decayed more. So over the last two thousand years there have been over one hundred comets with absolute magnitudes that made them intrinsically brighter than P/Halley.

Far from "punctuating history every 76 years like an exclamation mark", P/Halley is often overshadowed. The 1532 case was a typical example and one doesn't have to think long before 1680 and 1910 spring to mind.

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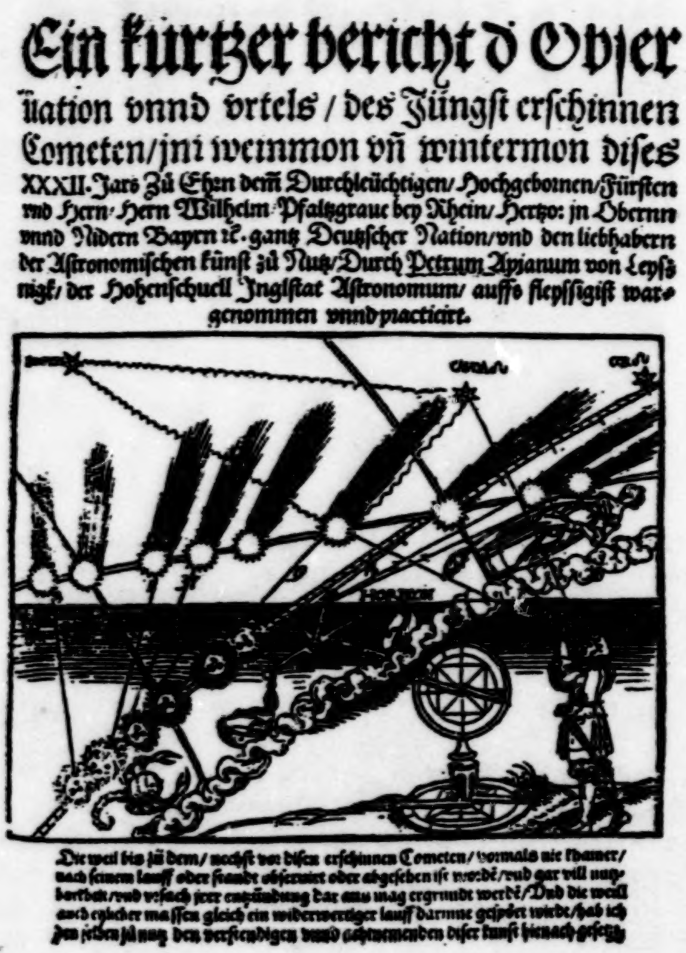

Ein kürtzer bericht d' Obser
uation vnnd vrtels / des Jüngst erschinnen
Cometen / jm weinmon vñ wintermon dises
XXXII. Jars Zů Ehen dem Durchleüchtigen / Hochgebornen / Fürsten
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vnnd Nidern Bayrn &c. gantz Deutscher Nation / vnd den liebhabern
der Astronomischen künst zů Nutz / Durch Petrum Apianum von Leyß
nigk / der Hohenschuell Inglstat Astronomum / auffs fleyssigist war
genommen vnnd practiciert.

Figure 1. The first page of Peter Apian's report of the observations of the comet of 1532.

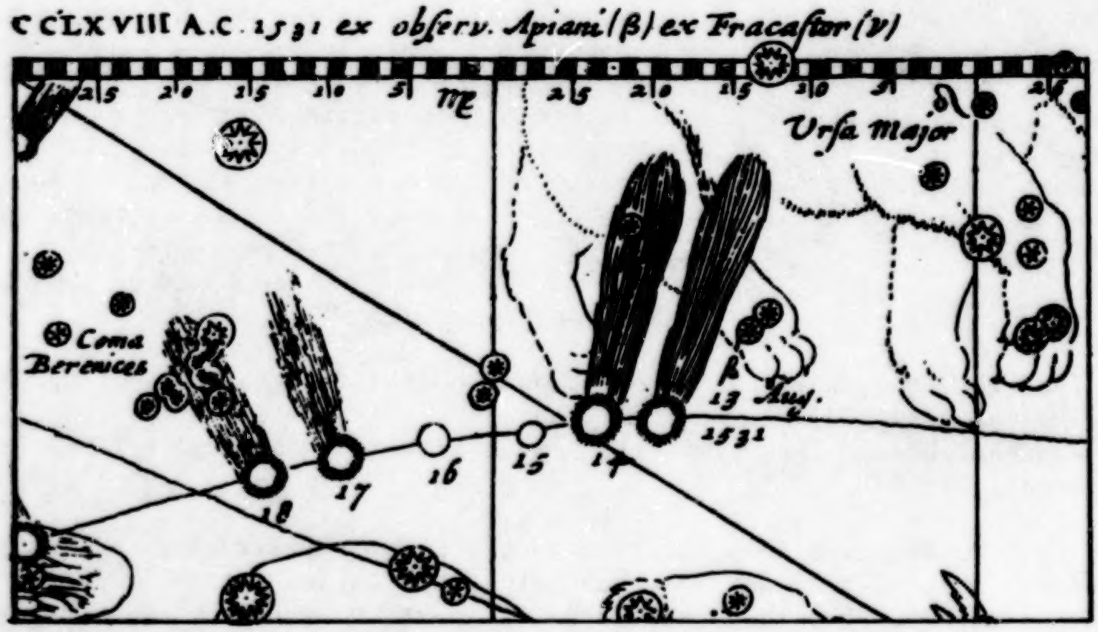

Figure 2. Part of the path of Halley's Comet in 1531.

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A PHOTOMETRIC LIGHT CURVE OF COMET HALLEY 1910 II

A. Magazzu
Osservatorio Astrofisico di Catania
Città Universitaria
I-95125 Catania
ITALY
and S. I. S. S. A., Trieste, Italy

G. Strazzulla
Osservatorio Astrofisico di Catania
Città Universitaria,
I-95125 Catania
ITALY

Editors' Note: The IHW Newsletter does not publish formal technical papers. We do not have the staff, the reviewers, or the facilities to do so, even if we wished to intrude upon the domain of the established journals. Occasionally, however, old Halley data are uncovered which should be brought to the attention of cometary scientists but which seem unsuitable for a technical journal. The following brief paper by Magazzù and Strazzulla describes just such data.

In 1910 Bemporad made an extensive series of observations of what we now call the "photometric nucleus." We do not clearly understand the nature of the photometric nucleus even today. Recent observations of the photometric nucleus of IRAS-Araki-Alcock provided many surprises and more questions than answers. Perhaps these unusual 1910 data may prove useful in understanding 1986 observations. Therefore we are most grateful to Magazzù and Strazzulla for bringing them to our attention. Their short empirical paper follows as submitted.

S. J. E. & R. L. N.

Abstract

In this paper we show a post-perihelion photometric light curve obtained for Halley's Comet during its last apparition in 1910. These observations are the most extended in time obtained by a single observer during the last passage of the comet and have not been previously quoted in the literature.

Introduction

In 1909-1910 the thirtieth recorded and the third precalculated apparition of Comet Halley (1910 II) was monitored by many observers using the best techniques available at that time. For extended bibliographical references see Vsekhsvyatskii (1964).

The comet was extensively observed at the Catania Observatory by visual, photographic, photometric, and spectroscopic techniques (Riccò, 1912). Photographic material has been recently sent to Dr. Jurgen Rahe to be included in the "Atlas of Comet Halley 1910 II - Photographs and Spectra" (see Rahe, 1981).

Here we show the photometric observations performed by A. Bemporad (1911). These observations have never been quoted in the literature. The interest of the present analysis can be connected with the missions to Halley's Comet scheduled for 1986 flybys by ESA (Giotto), the USSR (VeGa), and Japan (Planet A). For details on these missions see, e.g., Reinhard (1981).

Improved tactical planning for a P/Halley mission and related observing programs can hopefully be obtained through the analysis of the copious 1909-1911 observations and should also be useful in preparing for observations of various phenomena and the nucleus (Whipple, 1981).

Observations

Visual photometric measurements of the Comet Halley photometric nucleus (the portion of the comet of stellar appearance) were performed during 1910 in Catania (Bemporad, 1911) starting from April 19 (just at perihelion passage) and ending on July 4, when the comet became too faint to be observed with the available instrument. These observations are the most extended in time obtained by a single observer. To perform them a Toepfer wedge photometer was mounted on a 15 cm Cooke equatorial refractor with a focal length of 2.23 meters. A magnifying power of 75 times was used. The image of the nucleus appeared to be generally well defined and of stellar appearance.

The photometer consisted of a wedge of shade glass of a neutral tint inserted in the field of view of the telescope, and movable so that a star may be viewed through the thicker or thinner portions at will. The exact position is indicated by means of a scale. The light of different objects is measured by bringing them in turn to the centre of the field and moving the wedge from the thin towards the thick end until the star disappears. The exact point of disappearance is then read by the scale.

For comparison Bemporad used stars in the Muller and Kempf (1907) catalogue (PD) and other stars nearer to the comet in position and magnitude. The magnitude of each of these stars was obtained by comparison with those of the PD catalogue after testing showed that the difference of magnitude obtained with the two photometric systems was less than 0.1 mag. The change in magnitude corresponding to 0.1 cm on the wedge (i.e., the wedge constant) was 0.1622 mag as deduced from the comparison of about thirty pairs in the PD catalogue between magnitudes 3 and 8.

We have assumed more recent values for the magnitude of the standard stars, as given by Nicolet (1978) or Hoffleit (1964), and according to these values we have corrected the magnitude of the comet.

In Figure 1 the light curve of the comet, including our corrections, is shown. From this figure we can see that sudden increases in the luminosity (outbursts) were clearly observed on April 19, 25 and May 12 followed by rapid decreases. Intense activity on the nucleus and head of the comet was recorded on photographs, spectrograms and visually by other observers as well (see Vsekhsvyatskii, 1964).

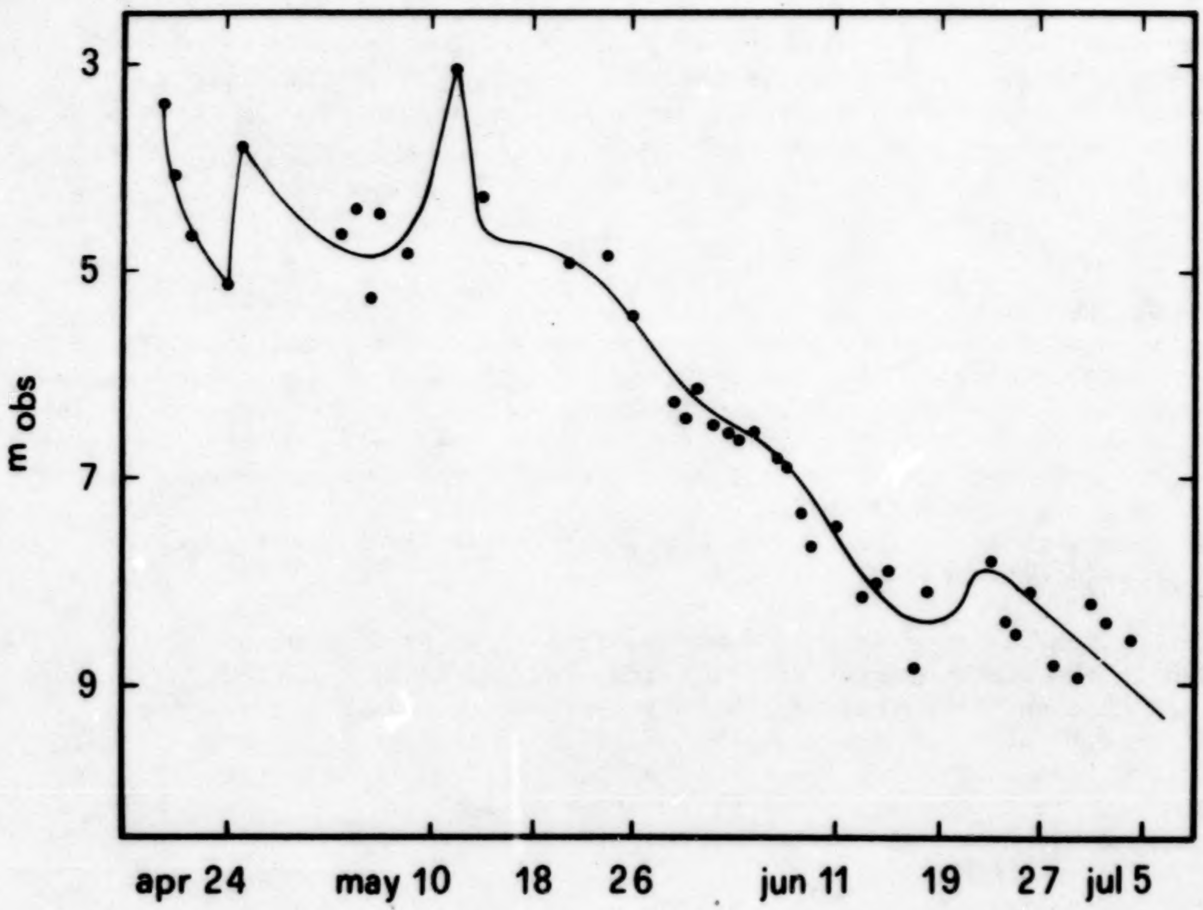

Figure 1. Postperihelion light curve of Halley's Comet (1910 II).

To fit the observed lightcurve Bemporad (1911) attempted to use the law

$$I = cr^{-n} \Delta^{-2}$$

where c is a constant and r and Δ are the sun-comet and earth-comet distances, respectively. He found that n changes from $n = 31.2$ (April 19 - April 25) to $n = 7.6$ (April 25 - May 12), to $n = 4.4$ (May 12 - May 23). These results induced Bemporad to conclude, understandably with the knowledge of his time, that the comet was shining by its own light.

Discussion and Conclusions

Cometary magnitude most commonly is represented by the formula:

$$m_{obs} = m_o + 2.5\ k \log \Delta + 2.5\ n \log r \qquad (2)$$

where m_{obs} is the observed total visual magnitude, Δ and r are the geocentric and heliocentric distances and m_o the absolute magnitude of the comet at $\Delta = r = 1$ AU.

Classically the brightness is assumed to vary as the inverse square of $\Delta (k=2)$ and m_o and n are determined by a least squares regression.

Since 1963 Opik has advocated the existence of a Δ effect based on physiologic reasoning according to which k should be chosen equal to 1 (Opik, 1963). In recent years Marcus (1981) was able to show for the first time the existence of a delta effect in the light curve of Comet Halley 1910 II and he found $1 < k < 2$.

To account for a possible delta effect we have solved eq. (2) by multiple regression (see, e.g., Bevington 1969) as well as by single regression assuming various k values. The results are shown in the table. In performing the regressions we have not considered the points on Apr. 19, 20, 21, 25, May 12, and June 23, 1910 because bursts were clearly observed (see Figure 1).

Solutions to Equation (2)

	k	m_o	n
multiple regression	0.78 ± 0.04	6.77 ± 0.04	3.62 ± 0.17
single regression	2	7.32 ± 0.05	1.90 ± 0.41
	1.5	7.10 ± 0.04	2.60 ± 0.21
	1	6.87 ± 0.03	3.30 ± 0.11
	0.5	6.64 ± 0.03	4.00 ± 0.11

In Figure 2 we show the m_Δ magnitudes ($m_\Delta = m_{obs} - 2.5 k \log \Delta$) versus log r for k = 0.78 obtained from the multiple regression, k = 2, and k = 1, and the straight lines that better fit them. We find that in two cases (k = 0.78 and k = 1) the fit is quite good.

We do not know if the results obtained have a precise physical meaning or if they are due to some systematic mistake in the observations. However we think Bemporad's observations merit airing to the modern scientific community and could be usefully compared with other observations made during the last passage of Halley's Comet.

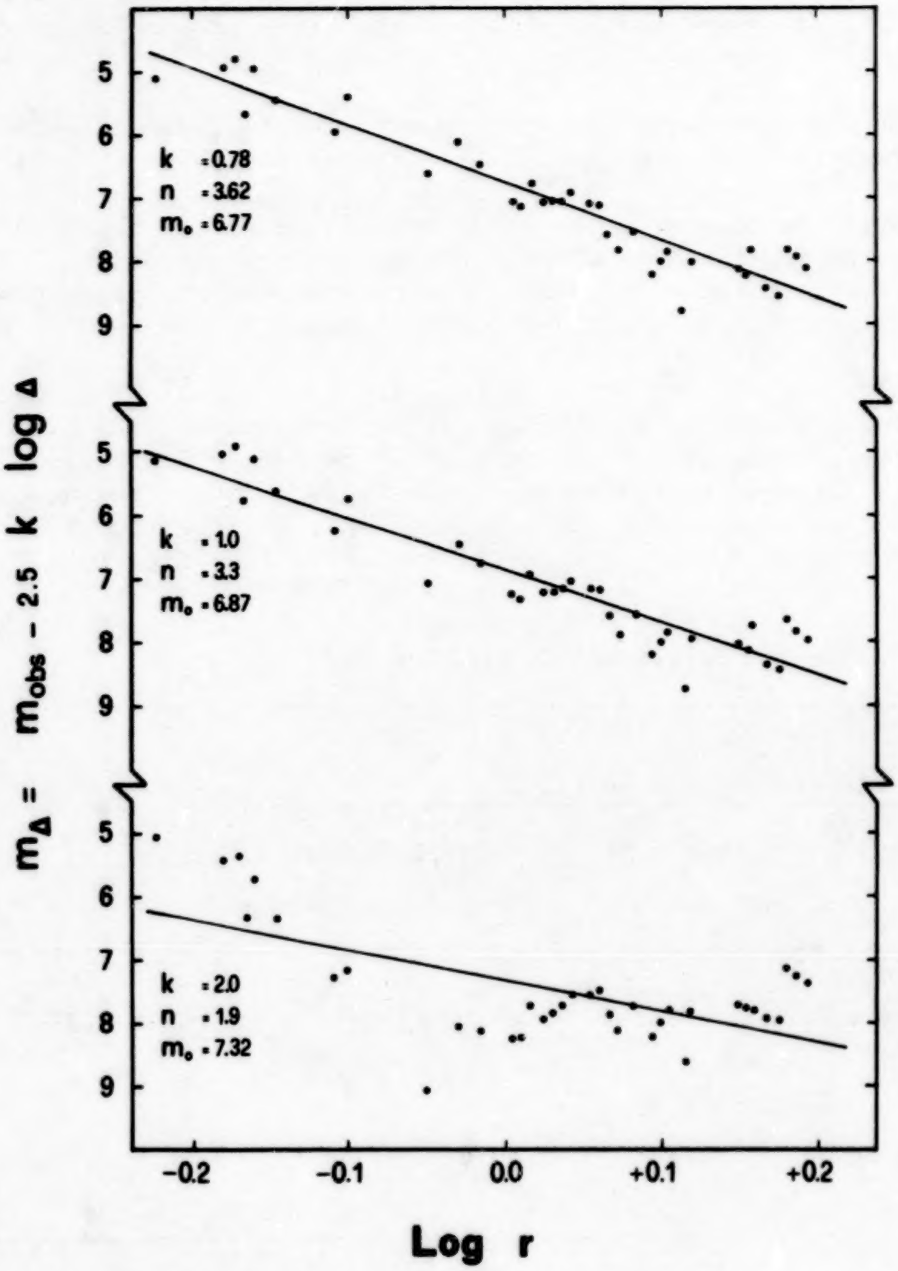

Figure 2. m_Δ versus log r for three different k values. The three straight lines are the best fit obtained by multiple (k = 0.78) or single (k = 1 or k = 2) regression.

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A STUDY OF THE DUST EJECTED FROM THE NUCLEUS OF PERIODIC COMET HALLEY IN 1910

Stephen Larson
Lunar and Planetary Laboratory
University of Arizona
Tucson, AZ 85721
USA

Zdenek Sekanina
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

ABSTRACT

We review the results to date of a study of the spatial and temporal distribution of dust in the coma of P/Halley. The data have yielded information on the particle density variations in the coma, orientation and rotation period of the nucleus, particle size range, some details of the dust emission process and what kind of behavior can be anticipated during the 1985-86 apparition. These studies were facilitated by the development of digital image processing techniques that enhance the visibility of dust density discontinuities in the coma on high resolution images taken in 1910.

INTRODUCTION

Since the cometary nucleus is small and unresolved with groundbased telescopes, most of our information about the physical nature of the nucleus must be derived from studies of the composition and the spatial and temporal distribution of the dust, gas and ionic components of the coma. We hypothesize that the observed spatial distribution of dust in the coma results from the initial conditions of ejection from the nucleus, and from the interaction with the local environment.

Most comets have a relatively simple coma where the gas distribution is isotropic and the dust is uniformly confined to a parabolic envelope resulting from the effects of solar radiation pressure on particles of a fairly narrow size distribution. In such cases, the nucleus is essentially homogeneous and probably rotating rapidly to produce the observed isotropic distribution. In some cases, there is a strong sunward asymmetry resulting from the preferential emission of material on the sunlit side of a slowly rotating or non-rotating nucleus. In both of these cases the lack of visible features in the coma indicates a homogeneous distribution of ices and dust in the nucleus. In all cases, the more or less uniform radial outflow of dust produces an observed column density, or brightness distribution in the inner coma that varies inversely with distance from the nucleus. This gives a long dynamic range of intensities (5 to 8 orders of magnitude) from the nucleus to the outer boundary of the coma, which is a major challenge to record photographically.

In some cases, the dust coma will show structure appearing as jets, arcs, envelopes or halos. In most of these cases, it is very difficult to record the coma structure because it is of intrinsically low contrast superimposed on the $1/r$ brightness distribution of the coma. The timescale of change of the coma

structures defines the temporal sample rate needed to follow their change and evolution. These are the primary problems confronting the Near-Nucleus Studies Net of the International Halley Watch as astronomers prepare for the 1985-86 apparition of Comet Halley.

As a means of better understanding the coma structure characteristics of Comet Halley, and to improve the techniques for data acquisition and analysis for the upcoming apparition, we undertook a study of the highest resolution photographs obtained during the 1910 apparition. Unlike the astronomers who took the photographs, we have modern, fast digital computers with advanced image processing capabilities at our disposal.

IMAGE PROCESSING

Analysis of the coma structure requires being able to detect and measure the structure boundaries. We first digitized the original plates obtained at the Mt. Wilson and Lick Observatories on the PDS scanning microdensitometer at Kitt Peak National Observatory. For compatibility with existing computer software, we produced 500 x 500 picture element arrays with each pixel equivalent to 1 or 2 arc second in size, depending upon the linear scale at the comet. Each pixel was 250 to 600 km across at the comet depending upon the comet's geocentric distance. Because there was no sensitometric calibration available for the plates, they were kept in the mode where the digital numbers are proportional to the plate density.

Various types of image processing algorithms were tried to optimize visibility of the coma structure. The major objective is to enhance the boundaries between the jets and the coma background. Since the dust is moving radially away from the nucleus in the inner coma, a shift-difference algorithm with a shift radial to the nucleus was developed. This algorithm produces pixel values that are the difference between their original value and those of pixels shifted by a specified distance in the direction radial to the nucleus. This results in a map of the rate of change of dust production at a given position angle with time. In some cases, coma feature boundaries are oriented radial to the nucleus and require a rotational shift-difference to see. The rotational shift-difference algorithm produces a map of dust production differences over the nucleus surface, especially in the inner coma. A combination of both radial and rotational shift differencing shows coma feature boundaries oriented in any direction. This is important since locally active dust emission regions change orientation on a rotating nucleus, and because jets become distorted by solar radiation pressure in the outer coma.

The optimum amounts of shift depend upon the digitized sample size, noise and characteristic feature edge gradient. A trial and error approach must often be used to find the optimum visibility of features on a given image. A drawback of the method is that because defects are multiplied three times, great care must be taken to avoid CCD defects and keep photographs clean. Interpretation of the processed images requires some care since dust density discontinuities are being displayed. In all cases, the unprocessed images are checked to verify the reality of coma features on the processed images.

CHARACTERISTICS OF DUST COMA FEATURES

The brightness of the jets can be compared to the general coma background to estimate the local dust concentration in the jets. Although the photographs

taken in 1910 were not sensitometrically calibrated, there are a few cases where there are exposures of different duration taken in succession that can be used to determine the characteristic curve of the emulsion. This approach assumes that the comet and sky conditions have not changed and that the plates were processed identically. In this study, one of the strongest jets was used to estimate an upper limit on the dust density. After conversion from photographic density to relative intensity, the projected surface brightness of the jet as a function of distance from the nucleus was compared with the same values for the coma outside of the jet. The unfiltered photographic emulsion was sensitive to a broad spectral bandpass defined by the atmospheric absorption and telescope transmission at shorter wavelengths and the emulsion response at the longer wavelengths. The comet's total brightness in the effective bandpass (3500-5000A) includes contributions by the gaseous emissions of CN, C_3, CO^+, CH, and C_2 in addition to the solar continuum reflecting off the dust particles. Convolution of the bandpass with spectra of the comet taken at about the same time indicates that the dominant flux is from dust and C_2. Using Haser's model for the gas distribution and the standard model for dust, it was possible to compensate for the gas contributions. The maximum line of sight contrast in the continuum was about 100%. Because the jets are confined to narrow emission cones, the actual particle number density in the jets can be as much as several tens of times higher than the average coma density. Although this result applies only to the very strong jets, their presence in a spacecraft's line of sight to the nucleus might produce significant contrast attenuation of nucleus features.

Comparison of enhanced images over several days reveals examples of spiral features that appear to "unwind" from the nucleus on the sunward side and then develop into expanding envelopes. This behavior suggests directed continuous emission from discrete sources on a rotating nucleus. As an emission source rotates on the nucleus, the emitted dust is initially confined to a conical surface whose vertex angle is twice the source's colatitude. The location of particles along this conical surface is a function of nuclear rotation period and terminal ejection velocity. This conical surface is soon distorted by the effects of solar radiation pressure on the particles. Perspective and projection effects due to variable viewing geometry and overlapping features often result in a very complex image that is difficult to interpret. A computer program that calculates the position of particles ejected at a specified velocity normal to the nucleus at various times and under the influence of specified radiation pressure was used to model the strongest features observed in 1910. The motion of the emission source with time is dictated by the spin axis orientation and rotation period (spin vector). By applying constraints such as the sense of the non-gravitational perturbations on the orbit and jet configuration, an interactive approach was used to match the measured feature boundaries with the models until satisfactory fits were obtained. The resulting spin vector solution could be tested by matching features observed over a range of viewing angles. The results so far indicate that the nucleus probably has a period of 40-44 hours, with an uncertainty of up to 10 hours. Information on the characteristic particle size (1-10 μm diameter) and elevation of the sun to trigger emission are also being obtained from the modelling solution.

A particularly interesting result of this type of analysis is the ability to determine the spatial and temporal distribution of active emission areas on the nucleus and therefore map the gross surface morphology of the otherwise unresolved nucleus. If emission areas have albedo variations and are not distributed uniformly around the nucleus, they might produce a spotted appearance that could result in a rotational light curve observable when the comet is

inactive far from the sun. Additionally, the distribution of nucleus inhomogeneities may provide information on the internal structure of the nucleus and the accretionary process during formation.

PROSPECTS FOR 1985-86

By studying the 1910 data, it is possible to better assess what will be observed during the 1985-86 period of maximum activity and what observational problems need attention to. In the context of the Near-Nucleus Studies Net, it is clear that images (both photographic and electronic) obtained by a well organized net will be capable of producing a map of active areas on the nucleus and study their changes with time. The appearance of strong jets that can be followed for several days is unpredictable. The 1910 results showed that the coma features were visible when the comet was within one Astronomical Unit of the earth and there was not a bright moon nearby. In addition to the designated International Halley Watch days, other periods which satisfy these conditions have been identified for all NNSN observers to improve the chances of recording these strong, diagnostic coma features. We are streamlining the image processing and modelling procedures for rapid analysis to aid the various flight projects in interpreting their very high resolution imagery.

The effect of anisotropic dust distribution on the spacecraft imaging experiments is very difficult to predict since particle densities and scattering properties are not known (Hellmich and Keller, 1981). The number of particles, and their scattering efficiency along the line of sight to the nucleus will determine the amount of contrast attenuation on nuclear features. For nominal trajectories, the spacecraft approach the nucleus from below the morning horizon before encounter over the sunlit hemisphere. Since the jets are observed to initiate emission only after the sun is above the local horizon, the spacecraft will probably not be hampered by dense jets until just a few seconds before the closest approach. If persistent source regions exist, they will be mapped from groundbased data prior to encounter, and it might be possible to link them with nucleus albedo features imaged by the spacecraft.

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1910 COMET HALLEY IMAGES DIGITIZED AT LPL

1910 MID-UT	ORIG. ID	PDS FILE	FILENAME	COMMENTS
May				
05.4896*	1-63 Wilson	11- 1	H630505	
05.4993	2-64 Wilson	11- 2	H640505	
06.4826*	3-66 Wilson	11- 3	H660506	
06.4924	4-67 Wilson	15- 1	H670506	
06.4992	5-68 Wilson	11- 4	H680506	
07.4826	6-69 Wilson	11- 5	H690507	
07.4931*	7-70 Wilson	11- 6	H700507	
07.5015	8-71 Wilson	11- 7	H710507	
08.4868*	9-72 Wilson	11- 8	H720508	
09.4868*	10-73 Wilson	11- 9	H730509	
09.5000	11-74 Wilson	11-10	H740509	
10.4811	12-75 Wilson	11-11	H750510	
10.4877	13-76 Wilson	15- 2	H760510	
10.4938*	14-77 Wilson	11-12	H770510	
11.4818	15-78 Wilson	11-13	H780511	
11.4872	16-79 Wilson	15- 3	H790511	
11.4922*	17-80 Wilson	11-14	H800511	
12.0795*	261 Helwan	14- 1	(H261)	
12.4760*	C2230 Lick	25- 1	(C2230)	
13.4674	C2234 Lick	24- 2	(C2234)	
13.4816*	C2235 Lick	25- 2	(C2235)	
14.4781*	C2236 Lick	25- 3	(C2236)	
14.4990	C2237aLick	24- 5	(C2237)	
15.0758	262 Helwan		(H262)	
15.	264 Helwan		(H264)	
15.4802*	C2241 Lick	25- 4	(C2241)	
****************** Solar conjunction **				
21.7406*	271 Helwan		(H271)	
21.	272 Helwan		(H272)	
21.	273 Helwan		(H273)	
22.1882*	C2253 Lick	25- 5	(C2253)	
22.7476*	276 Helwan		(H276)	Clockwise spirals
****************** Cross comet equator **************************************				
23.1809	C2255 Lick	24- 8	(C2255)	Counterclockwise spirals
23.1910*	C2257 Lick	25- 6	(C2257)	
23.7698*	285 Helwan		(H285)	
24.1802	C2260 Lick	24-11	(C2260)	
24.1944*	C2262 Lick	25- 7	(C2262)	
25.7514	287 Helwan		(H287)	
25. *	288 Helwan		(H288)	
25.7632	289 Helwan		(H289)	
25.	290 Helwan		(H290)	
26.2049*	C2268 Lick	25- 8	(C2268)	
26.7472	292 Helwan		(H292)	

1910 COMET HALLEY IMAGES DIGITIZED AT LPL continued

1910 MID-UT	ORIG. ID		PDS FILE	FILENAME	COMMENTS
26.7590*	293	Helwan		(H293)	
26.7826	294	Helwan		(H294)	
26.	295	Helwan		(H295)	
26.	296	Helwan		(H296)	
26.	297	Helwan		(H297)	
27.1809	C2272	Lick	24-14	(C2272)	
27.1910*	C2274	Lick	25- 9	(C2274)	
27.7611	299	Helwan		(H299)	
27.	300	Helwan		(H300)	
27.7507*	303	Helwan		(H303)	
28.1875	C2278	Lick	24-16	(C2278)	
28.2389*	C2280	Lick	25-10	(C2280)	
29.2389*	C2284	Lick	25-11	(C2284)	
30.1889	C2286	Lick	24-19	(C2286)	
30.1910*	C2288	Lick	25-12	(C2288)	
31.1910*	C2290	Lick	24-21	(C2290)	
31.2757*	C2293	Lick	24-22	(C2293)	
June					
01.1917*	C2294	Lick	24-23	(C2294)	
02.1785*	18-81	Wilson	15- 4	H810602	
02.1910	19-82	Wilson	11-15	H820602	
02.2122	20-83	Wilson	15 -5	H830602	
02.2267	21-84	Wilson	15- 6	H840602	
02.8212*	333	Helwan		(H333)	
03.1851*	22-86	Wilson	11-16	H860603	
03.2292*	23-87	Wilson	11-17	H870603	
03.7615*	336	Helwan		(H336)	
04.1948	24-88	Wilson	15- 7	H880604	
04.2253*	25-89	Wilson	11-18	H890604	
05.1938	26-91	Wilson	11-19	H910605	
05.2146	27-92	Wilson	15- 8	H920605	
05.2375*	28-93	Wilson	11-20	H930605	
06.2040	29-95	Wilson	11-21	H950606	
06.1889	30-96	Wilson	15- 9	H960606	
06.2182*	31-97	Wilson	11-22	H970606	

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ASTROMETRY
General

Recent Halley and Giacobini-Zinner Astrometric Observations

The first reported Halley observation during the current late-1983, early-1984 observing season was a 120 minute exposure from the Canada-France-Hawaii 3.6 meter Telescope on Mauna Kea, Hawaii. Dr. R. Racine reported that the Halley image was at magnitude 23.2 on Dec. 31, 1983. A series of 25 astrometric positions of Halley was reported by Drs. H. Pedersen and R. M. West for the time interval Jan. 27-30, 1984. These observations were made at the 1.5 meter telescope at La Silla, Chile. An analysis of the CCD photometric data will soon be published. Drs. M. J. S. Belton, H. Spinrad, P. A. Wehinger, and S. Wyckoff reported a Halley image at about magnitude 23.6 on March 4, 1984. This image was taken with the Kitt Peak (Arizona, U. S. A.) 4 meter telescope and represented the computer addition of eight 2 minute exposures using the CCD detector. A Kitt Peak group (S. Djorgovski, H. Spinrad, G. Will, and M. Belton) also reported the recovery of Comet P/Giacobini-Zinner with 4 CCD images taken on April 3, 1984. Confirmation (pre-recovery) images of this comet were quickly reported by Dr. R. M. West for Jan. 28, 1984 at La Silla (magnitude 24.5+) and also by Drs. Belton and Wehinger using the Kitt Peak 0.9 meter telescope on March 29, 1984.

Significant Progress on Halley and Giacobini-Zinner Star Catalogs

The Lick Observatory's "Comet Halley Faint Reference Star Catalogue" has been completed by Drs. A. R. Klemola, B. F. Jones, S. P. Francic, E. A. Harlan, and T. Nakajima. The Catalog includes 5148 stars within one degree of Comet Halley's path from January 1984 through late October 1985. The reference star catalog was the AGK3R, the equinox is 1950.0 and the approximate mean epoch is 1983.2. Most of the Catalog stars are in the visual magnitude range 13-14 with some stars in the wider range 11-15. The star density was chosen to be 30-40 stars per square degree. Under the direction of Drs. Yu. A. Shokin and N. M. Evstigneeva at the Main Astronomical Institute Sternberg (Moscow), a similar Halley star catalog effort is under way using the 40 cm astrograph at the Crimean Observatory. Dr. R. S. Harrington, of the U. S. Naval Observatory, has recently put together the first version of the Special Halley Reference Star Catalog. This catalog contains a total of 16,175 stars from various sources including the Lick Catalog, the Moscow Catalog, the AGK3, and southern stars from the 1984 version of the SAO Catalog. Still to come are approximately 600 stars from the U. S. Naval Observatory program and additional stars from the Moscow program. The special Reference Star Catalog for Comet Giacobini-Zinner, containing 2751 AGK3 stars, has also been completed by Dr. Harrington.

Astrometry Network Workshop Held June 18-19, 1984

Dr. R. M. West was our host at the Headquarters of the European Southern Observatory in Garching, FRG (near Munich). The objectives of this workshop were to discuss and set standards for the astrometric observations of comets, the reduction of this data, and using this data in accurate orbit determination computations. The use and distribution of special reference star catalogs for Comets Halley and Giacobini-Zinner as well as plans for stellar and radio source occultation predictions for both comets were also on the Workshop agenda.

Comet Crommelin Trial Run Results

The astrometric data received during the Comet Crommelin trial run has been encouraging. To date, a total of 283 observations have been received from 37 different observatories and many observers reported that poor weather conditions prevented their participation in the trial run. Upon request, a listing of a particular observatory's "observed minus computed" residuals will be sent to any observatory that took part in the trial run. In general the more experienced astrometric observers provided the most accurate data but a number of recently active observers also provided consistently accurate data. A number of Network improvements were suggested as a result of the trial run. Only a very few observers noted that they used the Comet Crommelin star catalog in their data reductions. While the Crommelin Star Catalog was simply a selection of SAO catalog stars, the Halley and Giacobini-Zinner Reference Star Catalogs will be special listings of reference stars along the path of these comets and observers are strongly encouraged to use only these Special Catalogs in their future data reductions. Observers are requested to send their data to both Drs. B. G. Marsden (Smithsonian Astrophysical Observatory) and D. K. Yeomans (Jet Propulsion Laboratory).

D. K. Yeomans
R. M. West
R. S. Harrington
B. G. Marsden

INFRARED SPECTROSCOPY AND RADIOMETRY

General

Comet Crommelin Trial Run

Participation in the Comet Crommelin Trial Run was at a gratifying level for what was a very faint comet in the infrared. Observations are summarized in Table 1 below and in the table prepared by T. Encrenaz in the accompanying report. As of 15 May, fourteen groups had responded to our request for information of successful or attempted observations. Table 1 includes successful detections (3), upper limits (2), and observations that failed because of weather or other reasons (3). Three (3) groups, not included in Table 1, had planned observations but did not observe for various reasons.

Problems that were encountered, besides weather, were the high air mass, short observing time, inability to find or guide on the comet, and inability to detect it. The reasons for the latter seem to be detector sensitivity and chopper modulation amplitude. It is fortunate that these problems were discovered during the trial run.

The experience of the observers, including the writer, is that practice observations of comets are very useful, almost a necessity. Observing a fast-moving, faint, extended object at high air mass in a short observing time with photometric accuracy can be challenging indeed! Some subset of these conditions will hold for Comet Halley. We would like to suggest that observers may wish to "practice" on other comets. A number of short-period ones will be available between now and the Halley apparition.

TABLE 1

Observations of Comet Crommelin

Asia and Western Hemisphere

Date	Telescope	Filters	Observers	Comments
3 March	3m IRTF	10, 20 μm	J. Gradie	photometry
6-7 March	1 m Nainital	J,H,K	T. Chandrasekhar	photometry
21 March	1.3m KPNO	J,H,K,L,M,N	R. Joyce	photometry
22-26 March	Peking	"infrared"	Liu Zongli Qian Zhongyu	
25-31 March	1m Yunnan	J,H,K,L	Chen Pei-Sheng	photometry
25, 26 March	1m Agematsu	K	T. Mukai S. Sato T. Nagata	photometry polarimetry
28-31 March	3m IRTF	J,H,K,L,M,N,Q	M. Hanner A. Tokunaga R. Knacke	photometry mapping
6 April	3m IRTF 88" Hawaii	J,H,K V	D. Cruikshank	photometry

Photometry of Comet Halley

Table 2 is a schedule of how the infrared observations of the IHW might run. Note that photometry will begin in early 1985; in fact, we can start searching for the infrared signal in the coming fall, 1984.

All of the suggestions on the table are, of course, qualitative, and people will want to follow their own plans and instincts. For example, our listing of "Near IR Photometry" is not meant to exclude attempts to detect the thermal emission at large heliocentric distances, a very important thing to do.

The schedule does show the need to make observing plans and proposals soon, especially for photometry. We know of several extensive photometric programs being organized to monitor the comet. If you are setting up such a program and have not contacted us yet, please let us know about it and keep us informed about your scheduled observations. We plan to keep a master schedule of all IR photometry so that complete coverage will be assured.

We continue to be ready to assist you whenever possible.

Roger Knacke

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Table 2

POSSIBLE SCHEDULE FOR IR OBSERVATIONS OF HALLEY

δ Declination; θ Sun-Earth-Comet Angle; M1, M2 Visual Magnitudes; R Heliocentric Distance

Date	δ	θ	M_1, M_2	R	Observation	Objective	Best Site	Frequency of Observation	Telescopes Dia., Number
1985 J	+12	162	0.0, 17.9	5.3			Hawaii		
F						Colors of Nucleus	Crimea	2 per month	
M	+13	94	0.0, 17.5	4.7	Near IR		Japan	(including	
					Photometry	Mass Loss	Europe	IHW days)	>2.5 m, 2-3
A							N. America		
M	+16	35	0.0, 17.1	4.1					
J									
J	+18	16	16.1		Limited to Telescopes Observing Near the Sun.				
A									
S	+19	66	13.1, 14.2	2.7		Ices			<1 m, 3-5
O					IR Photometry	Silicates		2 data sets	
						Partlicle Composition	Same	per month	1-2.5 m, 3-5
						Size Distribution		(including	
N	+21	136	8.7, 10.3	1.9		Evolution of Dust		IHW days)	
D						Search for Molecules			
1986 J	-2	55	5.4, 7.9	1.0	Spectroscopy				>2.5 m, 2-3
					(CVF)				
F					Limited to Telescopes Observing Near the Sun.				
M	-16	34	4.7, 6.6	.7	HRS (FP, FTS	Giotto and VeGa	S. Africa		
					(Heterodyne)	Support			<1 m, 3-5
A					Imaging		S. America		
					Same as above			All IHW days	
M	-18	128	6.0, 9.1	1.6		Search for parent molecules	Australia		1-2.5 m, 3-5
							Hawaii		
J									
J	-5	64	9.6, 13.6	2.5	IR Photometry				>2.5 m, 2-3
A									
S	-8	18	12.6 15.7		Limited to Telescopes Observing Near the Sun				
O									
N	-12	40	14.0, 16.7	3.9	IR Photometry		S. Africa		
D						Monitoring of dust		2 per month	
1987 J	-16	98	14.1, 17.2	4.5		properties	Australia	(including	>2.5 m, 2-3
								IHW days)	
F					Near IR	Mass Loss	S. America		
M	-13	158	0.0, 17.7	5.1	Photometry				

IR Observations of P/Crommelin in Europe

IR observations of Comet Crommelin were planned from January to March 1984 at ESO (Chile), OPMT (France), and UKIRT (Hawaii). However, that comet was too faint to be detectable in January. Photometric data were obtained in March 1984, before and during the IHW week, at ESO and UKIRT. Table 1 summarizes the results obtained by European observers. These results are in good agreement with the data obtained by M. Hanner and [illegible]. Knacke at the IRTF.

From these observations information will be derived on the nature of the dust particles (from the J,H,K,L,M fluxes), the dust spatial distribution (from the dependence of the flux versus the diaphragm size), and the dust temperature (from the thermal emission of the dust above 5 microns).

The reduced data have been sent to R. Knacke through the questionnaire (IHW infrared photometry observation summary).

Problems encountered during the campaign were: (1) the inadequacy of some IR photometers to observe very extended objects (the modulation amplitude was not always sufficient); (2) the inadequacy of some telescopes to track fast-moving objects; (3) the low elevation of the comet (which makes the dewar work in difficult conditions); (4) the short observing time available each night; and (5) the poor weather conditions in Europe in February and March. Since all these conditions will exist again for Halley (except the weather, hopefully!) a special effort will be made especially in increasing when necessary the modulation amplitude of IR photometers and in preparing tracking programs adapted to fast-moving objects.

Th. Encrenaz

TABLE 1

IR Photometry of Comet Crommelin by European Observers

Date	Time	Telescope	Filter	Aperture	Magnitude	Observer
84/03/19	OhUT	ESO 1m	J	30"	11.4±0.1	Engels
"	"	"	H	"	11.0±0.1	"
"	"	"	K	"	11.0±0.1	"
"	"	ESO 3.6m	J	10"	13.4*(?)	Krautter
84/03/27	6h.03	UKIRT 3.8m	J	6.2"	13.68±0.03	Eaton & Zarnecki
"	5h.87	"	H	"	13.38±0.03	"
"	5h.95	"	K	"	13.14±0.03	"
84/03/28	5h.80	"	M	5.1"	7.50±0.53	"
"	5h.88	"	8.7 μ	"	3.90±0.08	"
"	6h.18	"	8.7 μ	"	4.05±0.03	"
"	5h.62	"	N	"	3.49±0.03	"
"	6h.09	"	N	"	3.45±0.03	"
"	5h.98	"	12.5 μ	"	2.59±0.07	"
"	6h.28	"	12.5 μ	"	2.45±0.12	"
"	5h.71	"	Q	"	>1.7	"

* flux possibly underestimated

LARGE-SCALE PHENOMENA

General State of the Network

The Large-Scale Phenomena Network has witnessed an approximately 15% growth since the time of Newsletter No. 4, bringing the total to 90 participating facilities in 35 countries. N. Hemisphere coverage during the pre-perihelion time frame (1985 September-1986 January) is judged adequate for the recording of plasma-tail phenomena (where hourly time resolution is required), but post-perihelion coverage (1986 March-May) from the S. Hemisphere is spotty due to the paucity of facilities and the wide longitude ranges spanned by oceans. A major effort is now under way to outfit a small number of volunteer observers on suitable island locations with small portable Schmidt cameras (see below). Following is a more extensive discussion of several network activities.

Computer Image-Processing Effort

The L-SP Discipline Specialist (DS) team has identified absolute surface photometry of the plasma and dust tails as an extremely important computer image-processing activity to be applied to the images forwarded to the DS team. The scientific rationale is that the production rate of ions created in the head and injected into the plasma tail is variable in response both to the changing full-disk EUV solar radiation and to the varying input of the solar wind. Although qualitative changes have been noted in past comets, quantitative measurements have been almost completely lacking.

Our polling of network observers has shown that only about 59% of those who responded have intensity calibration of some form (e.g., tube spots). Inasmuch as many plates will be uncalibrated, and most of those which are calibrated will have relative intensities only, we have been working on a method which utilizes the profiles of standard stars in the field of view. (By no means are we discouraging the use of calibration spots by network observers; in most instances it will be very important to have them in order to check the star profile method). This effort was described briefly in the last newsletter; the method has been applied successfully by Dan Klinglesmith to several Schmidt plates of M31. A data tape of possible standards along Halley's path has been generated, a precursor to this activity being an estimate of the orientations and lengths of the comet's plasma and dust tails as functions of time.

A problem currently under study is the possible adverse effect of trailed stars in the derivation of absolute H and D curves.

"Island Network"

We have contacted the several U. S. and international organizations listed below:

U. S. Navy
British Antarctic Survey
British Meteorological Office
Comet Halley U. K. Coordinating Committee

The result has been a candidate list of possible island sites:

S. Atlantic	Indian	Pacific
Falklands	Mauritius	Easter
S. Georgia	Diego Garcia	Tahiti
St. Helena		Guam
Tristan Da Cunha		Caroline Isls.
Gough		

The modus operandi of the island network is that the DS team will, if necessary, supply a portable Schmidt and accessory set on a loan basis, and observations will be obtained by expense-paying volunteers. The above organizations are seeking volunteers and are exploring the means by which a training course can be administered (some volunteers may have little astronomical experience; the L-SP DS team will define the training course). A valuable supplement to the small Schmidt effort would be properly guided 35 mm photographs taken with telephoto lenses. Qualified individuals possessing such equipment are encouraged to contact us.

We would greatly appreciate the suggestions and views of all readers of this newletter who have opinions on additional sites, volunteers, etc.

Trial Run Results

Although Comet Crommelin was not expected to be a wide-field object, pre-trial run correspondence indicated that approximately 25 observatories intended to participate in the trial run. At the time of this writing, we have heard from six facilities, two of which were unable to photograph the comet due to poor weather. Glass plates were received from the Univ. of Michigan Curtis Schmidt (Dr. William Liller), Maria Mitchell Observatory (Dr. Emilia P. Belserene), and Catania Astrophysical Observatory (Dr. Salvatore Cristaldi). All plates were safely received and are presently being digitized and analyzed. The survival of the plates over large distances will, we hope, encourage observers to send carefully-packaged original plate material of Comet Halley in 1985-86. Not only will the analysis of the images benefit from having the original material (vs. film copies), but we will be more than happy to return any and all plates upon request. Film copies are, of course, acceptable substitutes, but their generation requires significant additional effort by the network observers.

Appropriately enough, the first trial run material we received--8" x 10" prints--came from the E. E. Barnard Observatory (Mr. Gary Emerson).

To those observers cited above, thank you for supporting the trial run effort. To those L-SP observers who did obtain Crommelin images but who have not yet forwarded them, please do so at your convenience. The comet may not have been spectacular, but our image-processing and archive design efforts would benefit from being able to examine your material.

L-SP Oservers' Manual

Presently in preparation by the DS team is an observer's manual for wide-field observations of Halley's Comet. Included in it will be information about the geometry and likely appearance of the comet, and ephemeris, recommendations about filter/plate/film combinations, observing strategies, etc. We hope to have these manuals mailed out sometime in late-1984.

J. C. Brandt
M. B. Niedner
J. Rahe

NEAR-NUCLEUS STUDIES

The recent activities of NNSN include the P/Crommelin trial run, a study of the available photographic data on P/Halley taken in 1910, and development of data reduction facilities.

P/Crommelin Trial Run

The Comet Crommelin trial run was a moderate success for the NNSN as CCD images were obtained on all trial run dates. The quality of data appears quite good, but the longitude coverage and amount of photographic data was not as good as hoped. Undoubtedly, part of the reason for this is that the comet was not bright, so all data came from apertures in the .9 - 2.3 m range. As it, turned out, the comet did not display any changing coma morphology. As the accompanying Figure 1 shows, the comet had a very weak dust (continuum) component that had the appearance of essentially isotropic emission. During the trial run, the dust coma was confined to an envelope produced by the effects of radiation pressure. The lack of a sunward asymmetry about the projected radius vector implies a short rotation period. There were no obvious day-to-day changes, but image processing has not been applied to all images. There was some evidence for ion tail activity in images taken earlier in the month, but these also will require closer study. Differences between broadband V and R images are slight even though the V images should have additional contributions from C_2 emissions. The best representative images will be submitted to the archive later this summer.

Study of 1910 Imagery of Comet Halley

The study of 1910 photographs was expanded to include plates taken at the Lick, Helwan, Heidelberg, Vienna, and Cordoba Observatories. As is expected in 1985-86, there were some cases in 1910 where the smaller telescopes provided the necessary time coverage to understand or verify the suspected evolution of coma features. Our 1910 data base now includes 76 digitized images with complete coverage over 33 days (with the exception of 5 days around solar conjunction). The first results of this study were published in the Astronomical Journal (Vol. 89, No. 4, April, 1984) and the second is scheduled for the September issue. The first paper presents the new image processing algorithm that enhances the visibility of coma feature boundaries and an estimate of the particle volume density increase in a strong jet from surface photometry. The second paper presents the particle distribution modelling method that permits deriving the nuclear rotation vector, typical particle size range, terminal ejection velocities, and emission sequence as a function of solar elevation. This paper

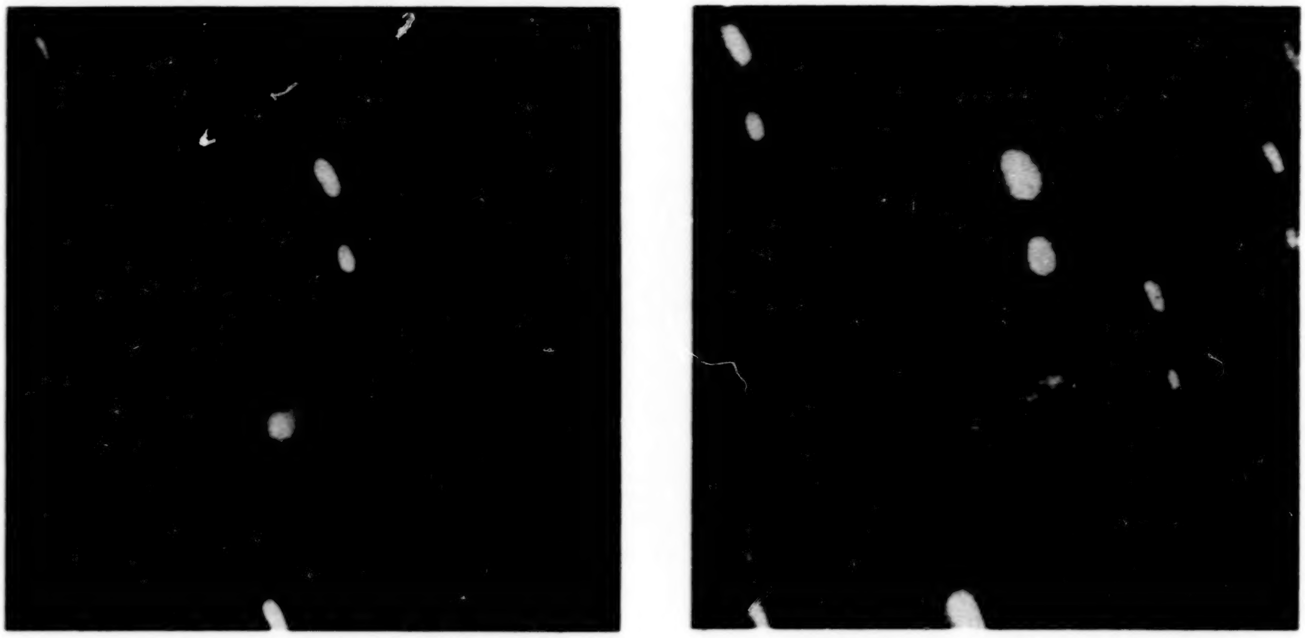

Figure 1. Unprocessed (left), and processed (right) versions of two co-added wide R-band CCD images of P/Crommelin on March 29, 1306 UT taken with the 154 cm Catalina telescope. The processed version is a result of a radial shift-difference about the point of maximum light of the comet. The edge of the field is 80,000 km at the comet, east is up and north is to the left.

also includes a discussion of the ramifications of the results for 1986 spacecraft. These papers demonstrate that it should be possible to produce a map of active emission areas on the nucleus from groundbased imagery in 1985-86. Subsequent papers will cover analysis of the newly acquired 1910 images. Reprints of these articles may be obtained by writing to either of the first two undersigned.

Rapid Data Analysis Facility

A major contribution that the NNSN can make is the rapid reduction and analysis of the high resolution images to be obtained in 1985-86 to support the flight projects. Concern is being expressed about the effects of jets of dust in the line of sight to the nucleus on spacecraft imaging experiments. The contrast attenuation produced by particle scattering is difficult to predict, but could be appreciable in the case of the strongest jets. For Giotto, a trajectory through a dense jet would substantially increase particle impacts and possibly affect attitude control. We are working on streamlining the image processing and modelling software to facilitate rapid output. The preperihelion images in 1985 will be used to refine the determination of the spin vector, identify active areas and typical active-area lifetimes. Images obtained postperihelion but prior to spacecraft encounters will be used to update the map of active areas in an effort to predict the location of jets that may interfere with spacecraft experiments. With this added task on NNSN, the need for more observers and rapid transfer of images becomes a more crucial issue. We will be working on better ways of implementing these plans in time for the major 1985-86 campaign.

S. Larson
Z. Sekanina
J. Rahe

RADIO SCIENCE

The Radio Science Net has had two significant trial runs in the last year: the official trial run on P/Crommelin and an unofficial trial run on an excellent target of opportunity, Comet IRAS-Araki-Alcock. Participation in these two trial runs has included 28 groups representing 9 countries around the world. Thus, virtually all of the world's major radio observatories have looked for (but not necessarily seen) a comet within the last year, and we anticipate a similar level of participation for Halley's Comet.

Although many of the participants in radio observations of these comets were unable to detect anything, there have been a few results that have provided us all with lots of incentive to observe Halley. Most notably, the detection of 1 cm lines of H_2O and NH_3 and the detection of continuum emission by the MPIfR group on the 100 m telescope on Comet I-A-A. Although the same group saw nothing in P/Crommelin, it is clear that the chances for success in observing these lines in Comet Halley are good.

Another promising sign for Halley observations was the excitement about comets displayed by the world's millimeter wave observatories during the passage of Comet I-A-A. Virtually all of the big mm dishes made attempts to detect parent molcules in the comet such as CO, HCN or more exotic species. No definitive detections were made (though some marginal detections have been reported), yet notably, the searches for HCN in the comet showed that its production rate was probably at least several times less than the production rate of CN at the same time. Thus, the radio observations suggest that HCN was not the parent of CN in Comet I-A-A. For Halley, it will be very interesting to see if a similar result is found and to begin to search for other possible parents of CN.

Finally, we were especially encouraged by the level of participation in the OH sub-net of the Radio Science Network during the trial run on P/Crommelin. OH observations of comets have been the single most successful cometary radio experiment, and it is therefore very important to attempt to have good coverage of Halley's Comet in these lines. It was apparent before the appearance of P/Crommelin that many of the observatories which stand an excellent chance of success on Halley's Comet would have great difficulty detecting P/Crommelin. Nevertheless, in the spirit of the Trial Run, observations were undertaken at 9 observatories around the world to attempt to detect the radio OH lines. All of the groups tried very hard, and at this time, we know of success at three telescopes at the level of about 10 mK antenna temperature: the Bonn 100 m telescope, the Nancay radio telescope, and the NRAO 140 foot telescope. Preliminary reductions suggest that the OH detections are consistent with OH production rates (normalized to 1 AU) of 1-2 x 10^{28}. There are also hints of double peaked lines, indicative of jets(?), in the data around Feb 14, 1984. Since Halley's Comet will typically be about 10 times brighter than P/Crommelin, the trial run proves that it should be possible to get high quality data from many sites around the world.

Our thanks to all observers for a job well done!

W. M. Irvine
F. P. Schloerb
R. D. Brown
E. Gerard
P. D. Godfrey

SPECTROSCOPY AND SPECTROPHOTOMETRY

Observations of Comet Crommelin (1983n): 1984 Feb-April

We have listed below the initial results of the Comet Crommelin Trial Run for the Spectroscopy Net. Observing sites are listed in order of longitude, starting at the International Dateline. The observations are not restricted to the week of the Trial Run, but rather extend over six months. Some closely related direct imaging data are also cited because these reports were filed with our center.

Hawaii: D. Cruikshank, Institute of Astronomy, University of Hawaii, writes that CCD images in R and V (70 x 70 arc sec) were obtained with the 2.24 m telescope on Mauna Kea, but no spectroscopic observations were made. R. Racine, Canada-France-Hawaii Telescope Corp., telexed that no spectra were obtained of Crommelin on that telescope.

California: H. Spinrad and S. Djorgovski, University of California, Berkeley, reported observations of Crommelin with the 3 m Lick Observatory telescope and a CCD with a 600 line grism, in the spectral range 6100-7500 Å at a resolution of 15 Å, on February 29, when Crommelin had R = 14.19 mag. [O I] 6300 and 6364 Å and numerous NH_2 emission bands were detected as shown in Figure 1 (courtesy of H. Spinrad).

Arizona: S. Larson, Catalina Observatory, Mt. Lemmon, University of Arizona, obtained spectra with the 154 cm telescope with a Cass. spectrograph and a multi-channel intensifier, recorded on 103a-D film, covering the spectral range 3000-5600 Å with a resolution of 15 Å and a slit length of 200 arc sec. Data were obtained February 1, 2, March 1, and 2. Emission bands observed included: OH, NH, CN, C_3, DH, C_2 Swan system, and NH_2. See Figure 2 for March 2 observations (courtesy of S. Larson).

Arizona: H. Spinrad, P. Wehinger, S. Wyckoff, and M. J. Belton obtained long slit (4.5 arc min) spectra with the Kitt Peak National Observatory 4 m telescope and a cryogenic camera (transmission grating and a Texas Instruments 800 x 800 pixel CCD), covering the spectral range 4600 - 8000 Å, at a resolution of 15 Å. Data were secured on February 4, 24, March 2, and 3. The usual emission features of the C_2 Swan system and CN (2-0) were observed, with unusually strong NH_2 emission features. The only molecular ions in emission were the (6-0) through (9-0) H_2O^+ vibronic bands, observed most strongly on February 24, and significantly weaker on March 2 and 3. No CO^+ emission was detected in the observed spectral range. One-dimensional sky-subtracted, flux-calibrated spectra have been reduced from the two-dimensional CCD frames. Direct CCD images were obtained nearly simultaneously by other observers on the same site. W. Romanishin used the KPNO 91 cm telescope on February 24 with an RCA CCD to obtain blue (4000-5000 Å) and red (6000-7000 Å) images. The red images showed a narrow plasma tail at the approximate position angle of the extended heliocentric radius vector. No tail-like structure was seen in the blue. On March 3, M. Sitko used the same telescope and detected weaker plasma tail features in the red (cf. IAU Circ., Nos. 3914 and 3927). A very weak plasma tail was detected in the red on March 28-29 again with the 91-cm telescope by M. J. Belton and P. Wehinger. A 4 m spectrum of Crommelin is shown in Figure 3. The direct CCD images obtained February 24 are shown in Figures 4a and 4b.

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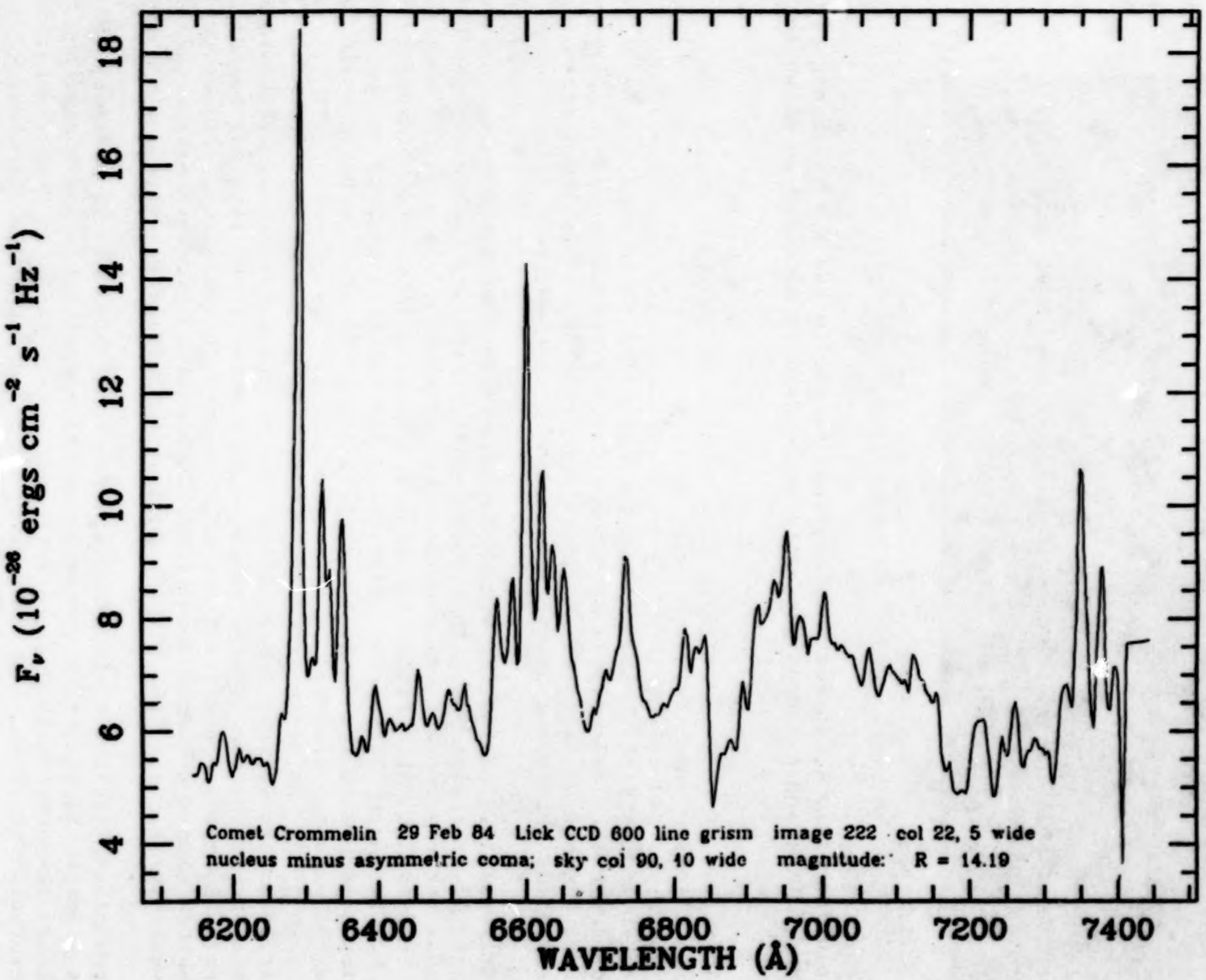

Figure 1. Spectrum of P/Crommelin obtained by H. Spinrad and S. Djorgovski at Lick Observatory on 29 February 1984 using a CCD 600 line grism.

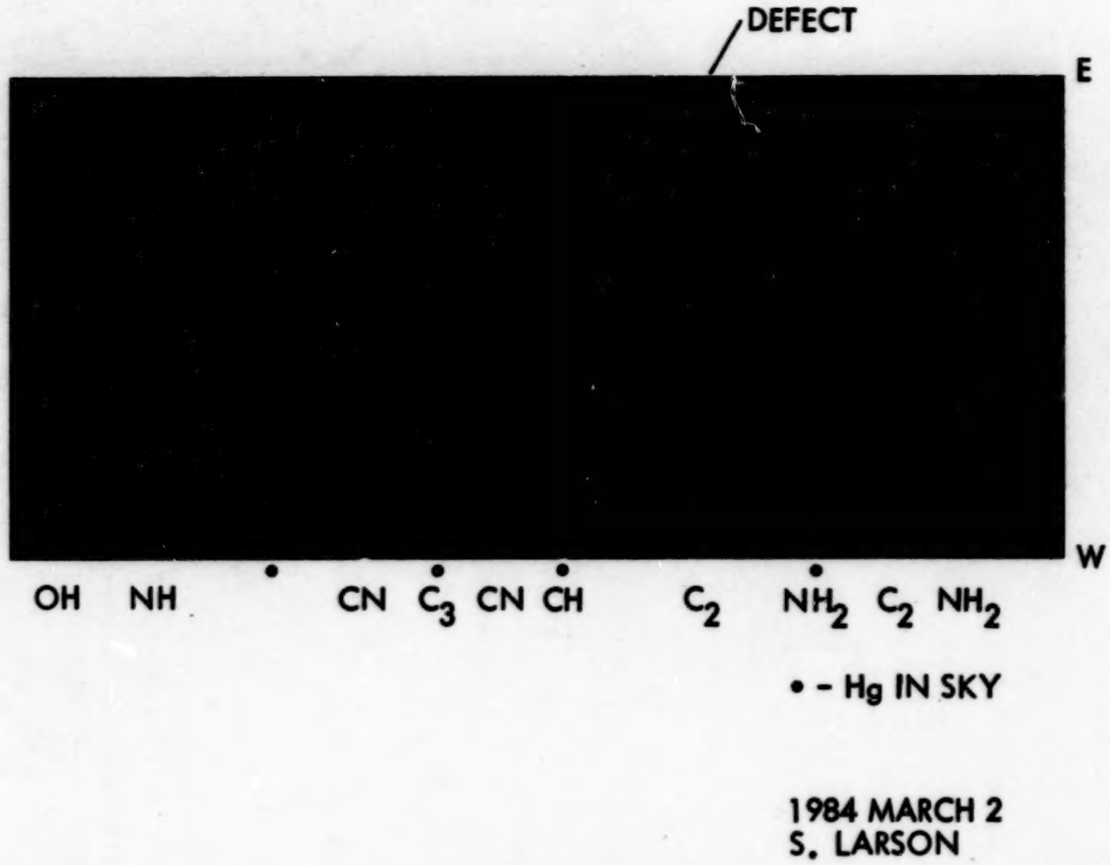

Figure 2. Long slit (200 arcsec) spectrum of P/Crommelin obtained by Steve Larson on 2 March 1984 using a microchannel plate intensifier on a 154 cm reflecting telescope. Night sky Hg lines are indicated by filled circles. Cometary emissions appear to be stronger in the anti-sunward direction.

Arizona: B. Lutz, R. M. Wagner, and S. Wyckoff used the Lowell Observatory, Flagstaff, 1.8 m telescope with a Cass. spectrograph and the Ohio State University image dissector scanner (dual aperture). They obtained data in the spectral range 3800-6400 Å, at a resolution of 9 Å. Observations were obtained on February 21, March 26, and 29. Sky-subtracted and flux-calibrated spectra of the coma of P/Crommelin, obtained February 21 and March 26, are shown in Figure 5.

Arizona: S. Wyckoff and D. Schleicher obtained spectra with the 4.6 m Multiple Mirror Telescope, F. L. Whipple Observatory, Mt. Hopkins, using a Cass.-type spectrograph with an intensified Reticon (dual aperture), covering the spectral range 3200-8000 Å at a resolution of 10 Å. Data were obtained on March 4.

Texas: E. Barker, A. Cochran, and J. Green, McDonald Observatory, University of Texas, obtained spectra with the 2.7 m telescope with a Cass. spectrograph and image dissector scanner (dual aperture) with a spectral range 3500-6500 Å and resolution of 10 Å. Data were obtained on two nights in March.

Chile: A. C. Danks, M. Dennefeld, M. Festou, and J. Lub, European Southern Observatory, La Silla, obtained spectra with the 3.6 m telescope with a Cass.

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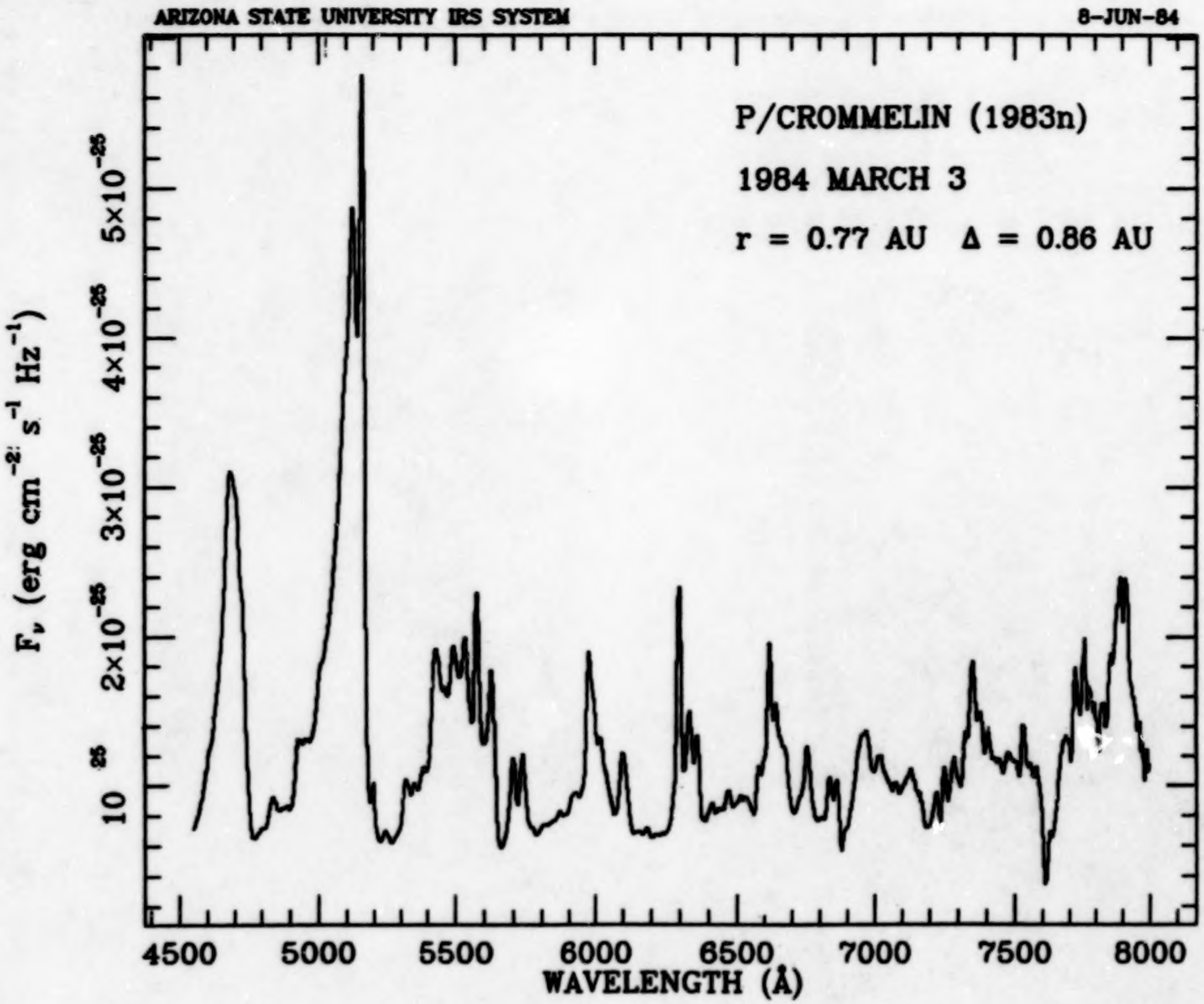
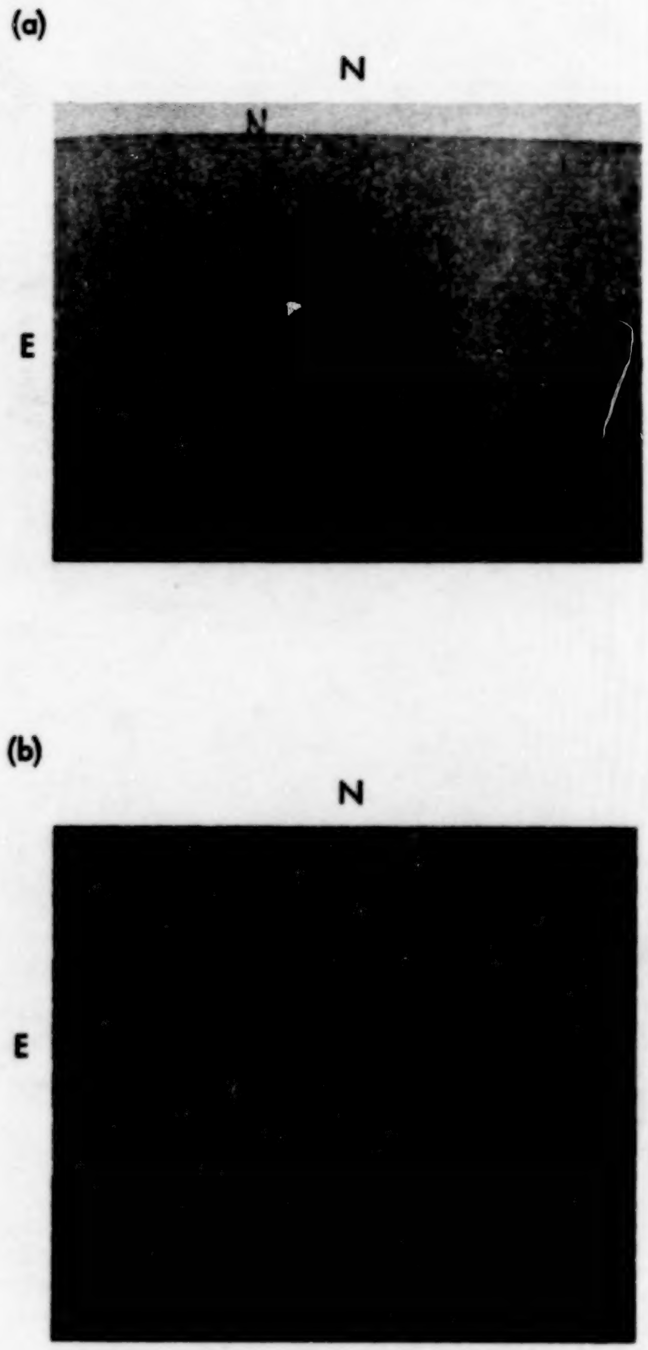


Figure 3. Spectrum of P/Crommelin obtained by H. Spinrad, P. Wehinger, S. Wyckoff, and M. Belton on 3 March 1984 using the KPNO 4 m telescope and cryogenic camera. The spectrum is a one-dimensional cut made across the two-dimensional frame at the location of the coma.



<u>Figure 4.</u> Direct CCD images of P/Crommelin obtained by W. Romanishin using the KPNO 91 cm telescope on 24 March 1984. (4a) Blue spectral region. (4b) Red spectral region. Note the tail structure in (4b) at a position angle of about 81 degrees.

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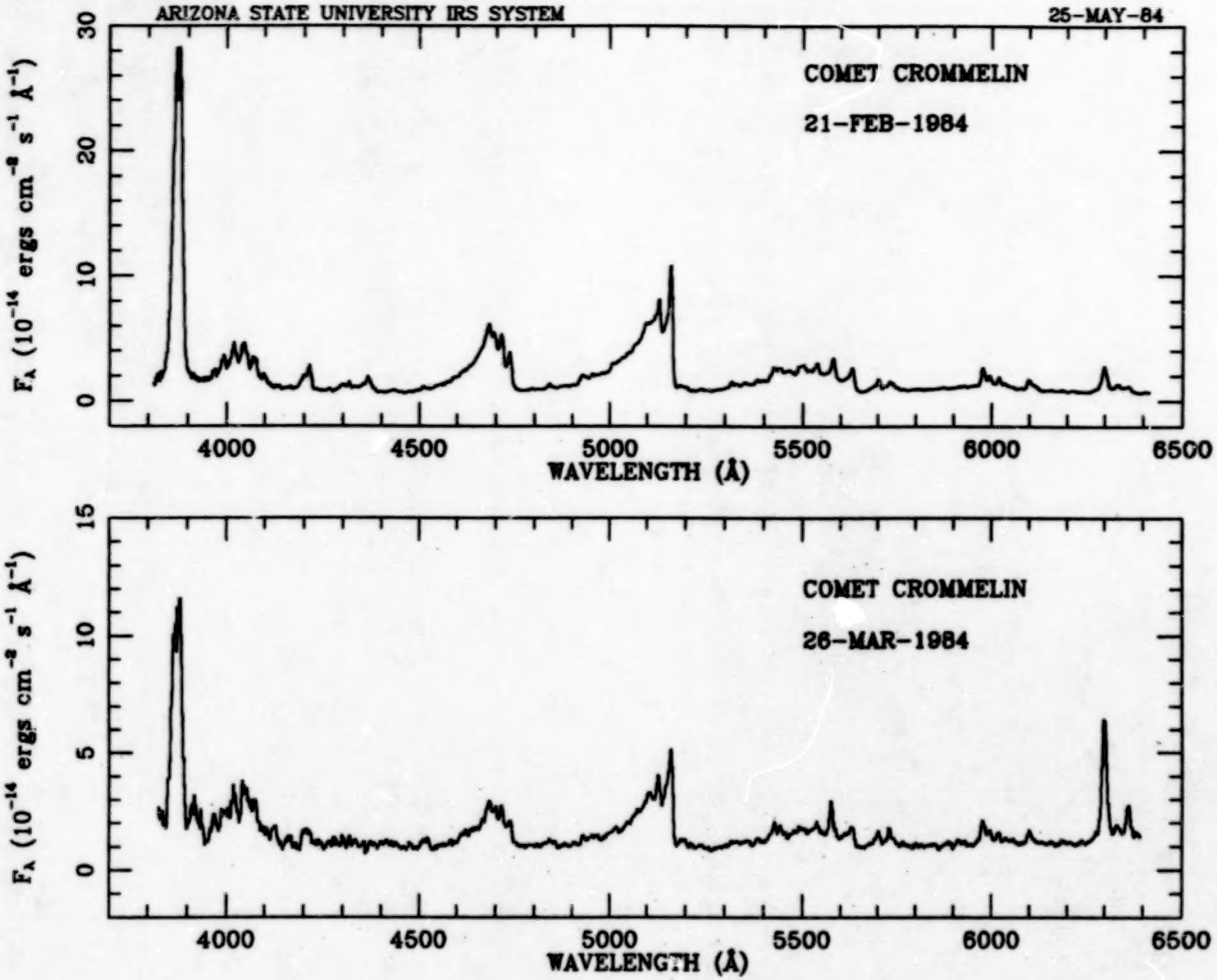

Figure 5. Spectra obtained of P/Crommelin by B. Lutz, R. M. Wagner, and S. Wyckoff at Lowell Observatory using a 1.8 m telescope and image dissector scanner. The upper spectrum was obtained near the time of perihelion passage (r = 0.74 AU) and the lower spectrum was obtained when the comet was at a distance of r = 0.98 AU from the sun.

spectrograph and image dissector scanner (dual aperture) over the spectral range 3800-7500 Å at a resolution of 15 Å. Numerous good low resolution spectra were obtained 1984 March 8, 9, 12, and 24. Activity in the nucleus was monitored. Production rates rapidly decreased after perihelion. During early March, Feldebok attempted to obtain high resolution observations but had technical problems. A. C. Danks writes that D. Cesarsky, Institute d'Astrophysique, Paris, obtained spectra with ESO/Max Planck Gesellschaft 2.2 m telescope with a Cass. spectrograph and an RCA CCD. The continuum of the comet's nucleus was detected and emission bands of the CN (2-0) red system were observed (cf. ESO Messenger, in press, 1984). See sample ESO IDS spectrum in Figure 6, obtained March 8 (courtesy of A. C. Danks).

Venezuela: N. Calvet, Observatorio National (CIDA), Merida, telexed that due to technical problems no spectra were obtained of Crommelin. They hope to be ready for future observations of other comets.

Spain: M. Festou and the European Comet Team, International Ultraviolet Explorer (IUE), obtained data Feb. 25, March 22, 30, and April 19, with complete UV coverage (1200-3400 Å) on Feb. 25, showing both HI and OH emission variations. For the Feb 25 observations, the derived OH production rate was $Q = 8.6 \times 10^{27}$ s^{-1}, while for S, $Q = 4.2 \times 10^{25}$ s^{-1}. Traces of CS 2576 Å were observed. Very weak continuum extended over several arcsec (cf. IAU Circ. No. 3921).

United Kingdom: P. J. Andrews, Royal Greenwich Observatiory, telexed "weather in UK atrocious for Crommelin time and La Palma (Canary Islands) telescopes not yet working, so we regret no observations were possible". (However, by late 1984, the 2.6 m Isaac Newton Telescope and a 1 m telescope will be in operation with an IPCS and CCDs - Ed.).

France: M. Festou and M. Dennefeld, Observatoire de Haute Provence, observed with the 152 cm telescope with a Cass. spectrograph in the spectral region 4000-5000 Å at 110 Å/mm. Data were obtained on two nights between Feb. 14-21.

France: M. Dennefeld and Y. Andrillat, Observatoire de Haute Provence, 193 cm telescope with Cass. spectrograph and a Reticon, spectral region 7000-10000 Å. Data were obtained one night between Feb 15-24. Strong CN 2-0 emission was observed around time of perihelion.

Republic of South Africa: Peter Mack, South African Astronomical Observatory, telexed that while no spectra were obtained, CCD images with Giotto filters were made with a 1 m telescope at Sutherland between March 27 and April 2. He also reported astrometric plates were obtained in Cape Town.

Ukranian S.S.R.: R. Korsun, Kiev Main Astronomical Observatory, Ukranian Academy of Sciences, telexed a report of observations with the 60 cm telescope equipped with the UAGS spectrograph and image intensifier, 101 Å/mm, recorded on Kodak 103a-G and A600P film over the spectral region 4500-6800 Å. Data were obtained 1984 Feb 28, March 2, 4, and 6. Features observed: C_2 Swan system and many faint NH_2 emission bands. Three spectra showed unusual detail in the region 5275-5375 in the anti-solar direction extending 1.8 arcmin with a maximum (intensity -Ed.) 42 arcsec from the center of the continuous spectrum. (Korsun did not suggest an identification for this feature -Ed.)

Israel: E. Leibowitz, Wise Observatory, 1 m telescope with a Cass. spectro-

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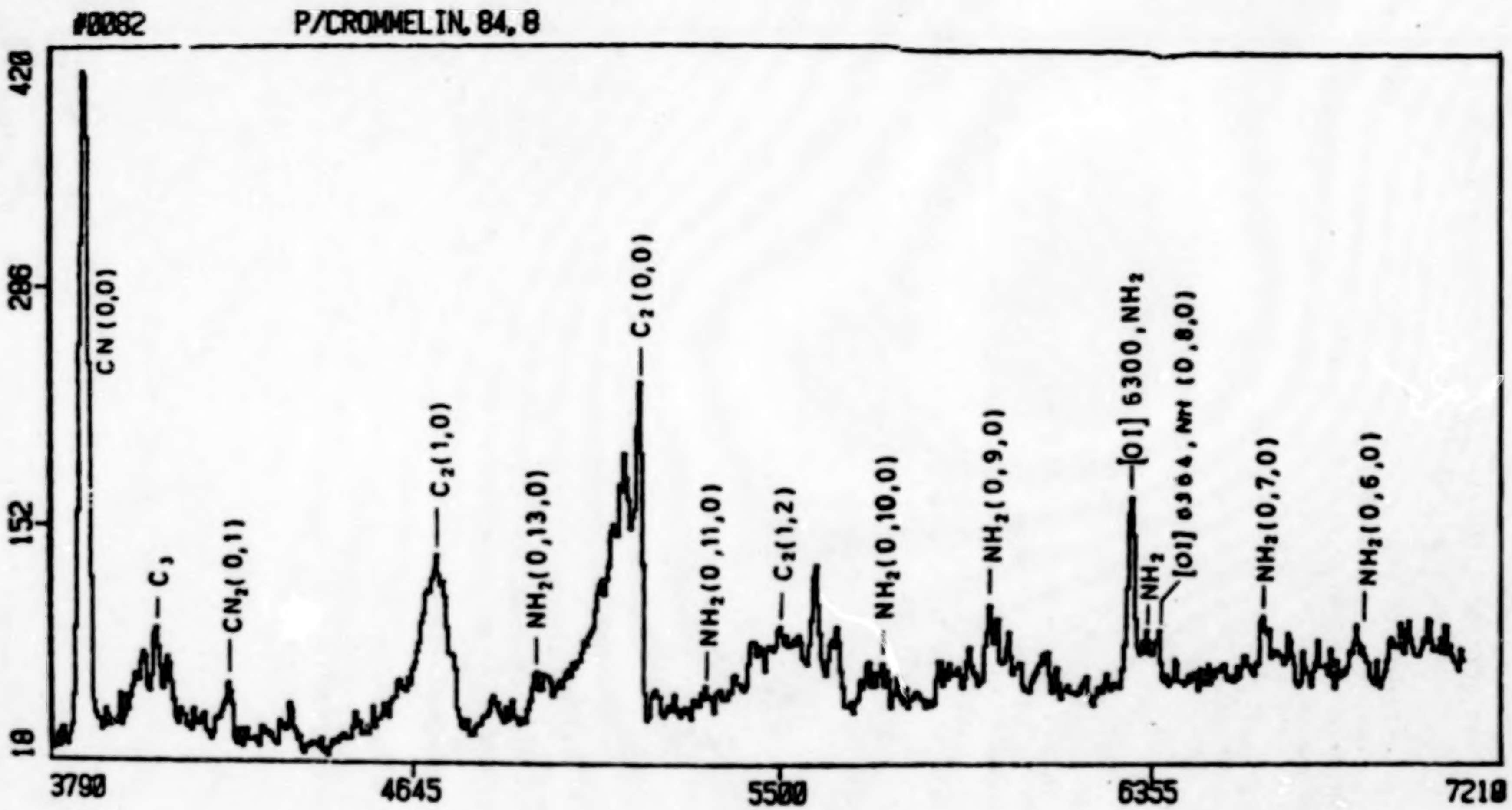

Figure 6. Spectrum of P/Crommelin obtained at ESO using the 3.6 m telescope and image dissector scanner by J. Lub and R. de Grijpe on 8 March 1984. The spectral resolution is about 15 Å.

graph and a Digicon. Leibowitz and his colleagues had planned observations during the Trial Run but had cloudy weather. He suggests that another trial run prior to Halley would be very useful.

People's Republic of China: S. M. Gong, Purple Mountain Observatory, Nanking, telexed that no spectra of Crommelin were obtained by his Chinese colleagues. (At the Kunming Observatory in Yunnan Province, a 2 m telescope to be equipped with an RCA CCD is under construction -Ed.)

Japan: T. Tsuji, Tokyo Astronomical Observatory, writes that observations were made by S. Tamura (Tohoku University), K. Saito, and K. Tomita (Tokyo Astron. Obs.), using the 91 cm telescope and Cass. spectrograph IDARSS system at the Dodaira Station.

Electronic Mail

Starting in February 1984 several types of electronic mail systems were implemented in the IHW Spectroscopy Center at Arizona State University. The first of these was the IAU Circulars, which are now implemented on a VAX at the Center for Astrophysics. Instant access to current IAU Circulars is therefore possible via telephone link. Observers can make contributions to the Circulars, which are edited by B. G. Marsden and appear within one or two days after they are received. This mail system is user friendly. Interested observers who would like to initiate this service should write to:

Dr. Brian G. Marsden
Central Bureau for Astronomical Telegrams
Center for Astrophysics
60 Garden Street
Cambridge, MA 02138
USA

Another electronic mail system has been set up at the IHW Spectroscopy Center on our VAX computer to receive information, questions, suggestions, etc. from net members. To log on, a remote user dials 602-965-2425 for the VAX modem link. For Username the user simply replies: NET. During the coming months we will have a set of osculating elements for Comets Halley (1982e) and Giacobini-Zinner (1984f) which observers can use with a two body program to calculate current ephemerides.

In addition to the electronic mail systems, we have installed a telex machine which is leased from TRT Telecommunications. The telex is located in our Spectroscopy Center offices and served as a valuable link to observers in all parts of the world during the Trial Run. To contact us via telex use the following:

Telex Number: 140289

Answerback Code: HALLEY ASU UT

No elaborate address is needed when a message is sent to us, thus providing a saving for the sender. The typical rate for a telex sent to Western Europe is about $2.00 per minute (66 words). If for any reason the above telex number does not work, telex messages can also be sent to another telex machine located elsewhere on the Arizona State University campus:

Telex Number: 667391

Answerback Code: ARIZ ST U TMPE

Here it is useful to add: "Halley Watch, phone 965-1986" at the beginning of the telex message to speed its delivery to our office.

Faint Solar Analog Standards

There is clearly a need for faint (12-14 mag) solar-type standard stars to be observed spectroscopically while P/Halley and other comets (e.g. P/G-Z) are faint. These spectra can be used to remove the reflected solar continuum from each of the cometary spectra (see Spectroscopy and Spectrophotometry Bulletin No. 1). Hyron Spinrad has suggested that stars in the old galactic cluster, M67, be observed for this purpose. See Eggen and Sandage (1964) Astrophys. J., 140, 130. In this paper, coordinates, a finding chart, and photometric data (V, B-V, and U-B) are given. One need only pick out stars with B-V = 0.60 and U-B = 0.12 at a suitable V magnitude. Furthermore, M67 is well situated [RA 08^h $49^m.0$; Dec +11° 58' (1960)] for P/Halley observations until about November 1985. We plan to obtain spectra of these stars later this year to verify their suitability as solar analogues.

Flux standard star manuals compiled by K. Strom, IIDS Standards, and by J. Barnes and D. Hayes, IRS Standards, are being printed at Kitt Peak National Observatory and will be available to spectroscopic and photometric observers on request. These manuals are expected to be available by September 1984 and can be obtained through the Lead Center at JPL. Address your requests to:

Flux Standard Star Manuals
IHW - Mail Stop T-1166
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
USA

CHARTS OF HALLEY FIELDS

On the basis of the difficulty in acquiring P/Crommelin in November 1983 to obtain spectra of it at 17-18 mag, we suggest that large scale finding charts of the P/Halley fields for key dates during late 1984 and 1985 be prepared. Such charts might cover the track of Halley until it is 15/16 mag, i.e. until 1985 November. Prints of the Palomar Sky Survey enlarged 10 times should help observers who seriously plan to observe Halley. Such charts would be most valuable for both photometrists and spectroscopists.

As an additional aid to observers, the Center for Spectroscopy will send observers hourly ephemerides for the IHW days. Osculating elements for P/Halley and P/Giacobini-Zinner are available from us. These elements can then be used with Yeomans' or other two-body ephemeris programs.

Molecular Emission

During the next year, the molecular emission listed in Table 1 may be expected to "turn on" in P/Halley. The observable emission features will, of course, be daughter products of the volatiles listed below (except for ions and Na I), which are excited by resonance fluorescence.

TABLE 1

Molecular Sublimation And Heliocentric Distance

r(AU)	Molecule	Remarks
≤ 7	H_2S, CO_2	Sublimation
≤ 6	NH_3	Sublimation
≤ 5	$NH_3 \bullet H_2O$, SO_2	Sublimation
≤ 2	H_2O^+, CO^+	First detectable
≤ 8	Na I D	Sputtering
≤ 5	Na I D	Sublimation

Spectra of two comets at large heliocentric distances are shown in Figure 7. The upper spectrum is of P/Smirnova-Chernykh at 3.6 AU, obtained by S. Wyckoff and D. Schleicher using the 4.6 m Multiple-Mirror Telescope with an intensified Reticon system. The lower spectrum is of P/Russell IV (1984d) at 2.2 AU, obtained by R. M. Wagner using the Steward Observatory 2.3 m telescope, also with an intensified Reticon. The system response and extinction have been corrected for P/Russell, while P/Smirnova-Chernykh is shown uncorrected. The spectra of comets at large heliocentric distances are dominated by reflected sunlight. P/Halley may exhibit similar spectra at comparable heliocentric distances.

International Halley Watch Days 1984-85

During the coming months, June-October 1984, the column density of sublimation products may be sufficient for spectroscopic detection of the atmosphere of P/Halley as the heliocentric distance decreases from 7.5 to 6 AU. The total magnitude will brighten from 22 to 18 between June and October. The rate of rotation, size of the nucleus, and nuclear albedo are very uncertain, and all control the rate of increase in brightness of the comet. Thus values for m_1 (total mag) and m_2 (nuclear mag) are still very uncertain. In any case, during the 1984-85 observing season, observers with access to telescopes of 2 m aperture or larger should be able to obtain low resolution (10-15 Å/mm) spectra of P/Halley as the coma begins to develop. Observers who are not comet specialists, but who may observe similarly faint extragalactic objects, should note that spectra obtained of Halley, or any other comet, beyond 3-4 AU are unique. Such spectra will provide essential input data for models of the developing cometary coma and its ionosphere. A list of IHW Days is presented elsewhere in this issue.

Comet Rendezvous Mission

Images and spectra of P/Wild 2, one of the comets chosen for study for the NASA Comet Rendezvous Mission (1990-91), were obtained at Kitt Peak National

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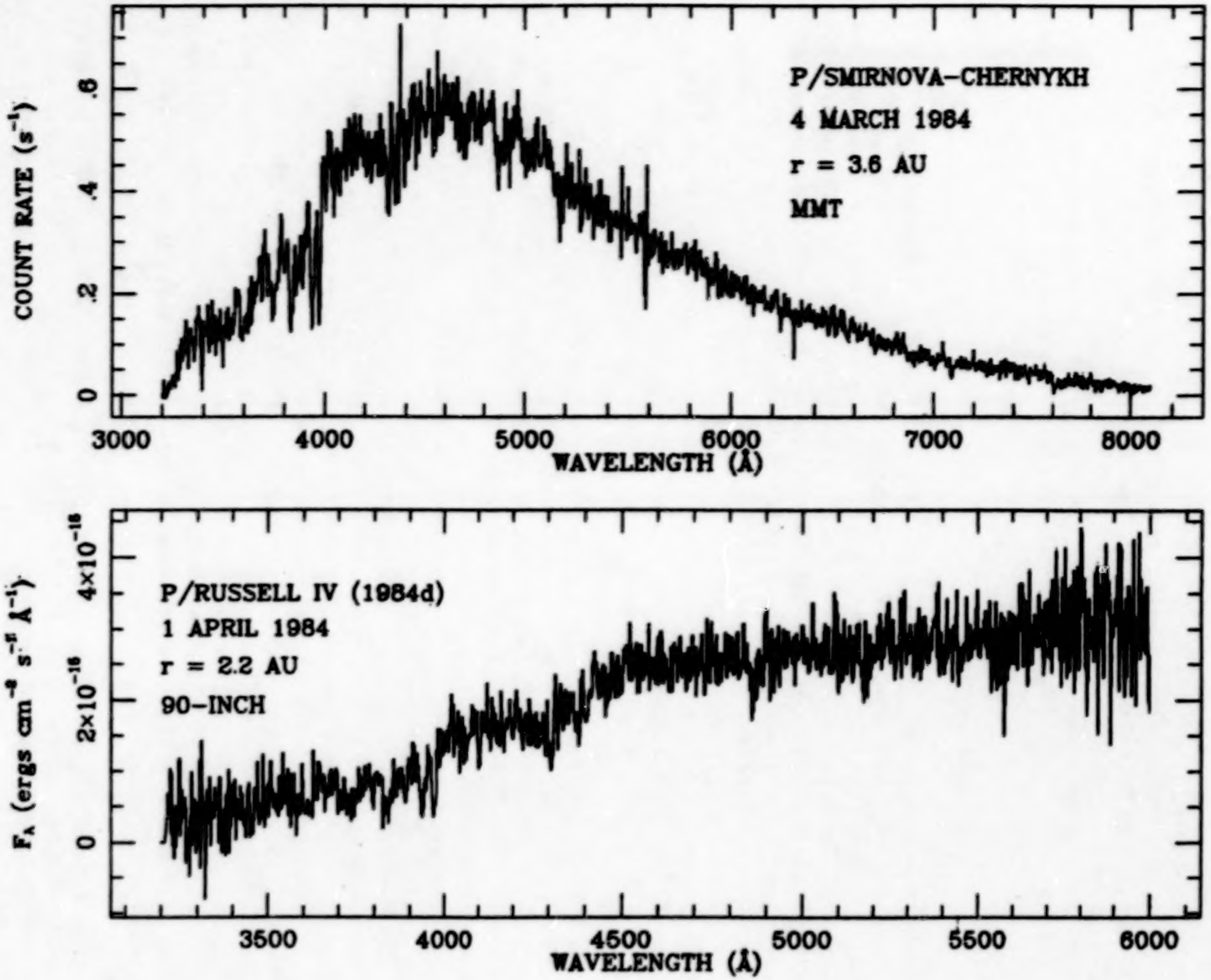

Figure 7. Spectra of two comets at large heliocentric distances. The upper spectrum is of P/Smirnova-Chernykh at 3.6 AU and the lower spectrum is of P/Russel IV (1984d) at 2.2 AU. Note that the spectra are dominated by a reflected solar continuum.

Observatory, 1984 Jan 4 and March 4, by M. J. Belton, H. Spinrad, P. Wehinger, and S. Wyckoff. The observations, made with the 4 m telescope and cryogenic camera, showed Wild 2 to have a well-developed coma at 2.5-2.0 AU, a strong dust continuum, and a broad dust coma. Tail structure was detected with p.a. = 96 deg. [O I] 6300 Å was detected January 4. CCD images on March 4 gave m_1 = 14.4 and m_2 = 17.7 V mag. (see IAU Circ., No. 3927).

Additional spectra of P/Wild 2 were obtained on January 20 by B. Lutz and R. M. Wagner at Lowell Observatory using the 1.8 m telescope and image dissector scanner. A sample of these spectra, which has been sky subtracted and flux calibrated, is shown in Figure 8. Comet Wild 2 was at a heliocentric distance of 2.5 AU and the spectrum was dominated by a reflected solar continuum. Lutz and Wagner find m (5556 Å) = 14.4 ± 0.2 mag using a 7 arcsec diameter aperture.

Recovery of P/Giacobini-Zinner

The recovery of Periodic Comet Giacobini-Zinner (1984e) was announced on 1984 April 12 (cf. IAU Circ., No. 3937). These observations represent an example of electronic mail and state-of-the-art image processing working together very effectively. On April 3, observers using the Kitt Peak National Observatory 4 m telescope (S. Djorgovski, H. Spinrad, G. Will, and M. J. Belton) obtained four 150 sec integration images of the predicted field of P/G-Z based on D. Yeomans' ephemeris. Djorgovski reduced the photometric data immediately after their observing run and derived a magnitude of 22.9 ± 0.1 (Bessel R filter), while Belton did the astrometry. A composite image was made on the KPNO Interactive Picture Processing System (IPPS), clearly showing a starlike image at the predicted position of the comet, with trailed images of the surrounding starfield.

These data were communicated to the Central Bureau of Astronomical Telegrams on April 9 by electronic mail from Arizona State University. Shortly thereafter we received a suggestion from B. G. Marsden that independent data obtained on another telescope or on another night would make the recovery much more certain. Meanwhile Yeomans had put the four astrometric positions out on the IHW electronic mail and soon they were read by R. West at ESO in Garching. West then had another close look at the ESO 1.5 m CCD images (30 min integrations) obtained on 1984 January 29 (by West and H. Pederson) with tighter windowing of the intensity range. Also, prior to the KPNO 4 m observations, Belton, Wehinger, Wyckoff, and Spinrad had obtained two CCD images with the KPNO 91 cm telescope on March 29 with 30 and 40 min integrations through a Mould R Filter. These images were reduced on the IPPS by Belton on April 10. By April 11 reports were sent to Marsden by West and independently by Belton and his colleagues, reporting very faint stellar images (about 23rd mag) within 3 arc sec of the predicted position of P/G-Z. The ESO January 29 and KPNO March 29 observations are now referred to as pre-recovery observations, which were important in helping to confirm the recovery in the April 3 data.

Finally we should mention that in May 1983, Spinrad, Djorgovski, and Belton had initiated a search for P/G-Z using the KPNO 4 m telescope. They obtained one 20 min integration CCD image (with the Cryogenic Camera) and reported a very faint image within 2.7 arc sec of the predicted position of P/G-Z. However, they were unable to secure additional data on another night during the 1983 season. Hence some eleven months passed before the recovery of periodic Comet Giacobini-Zinner could be announced with certainty. The 1984 observations represent the recovery of the second comet fainter than 22nd magnitude.

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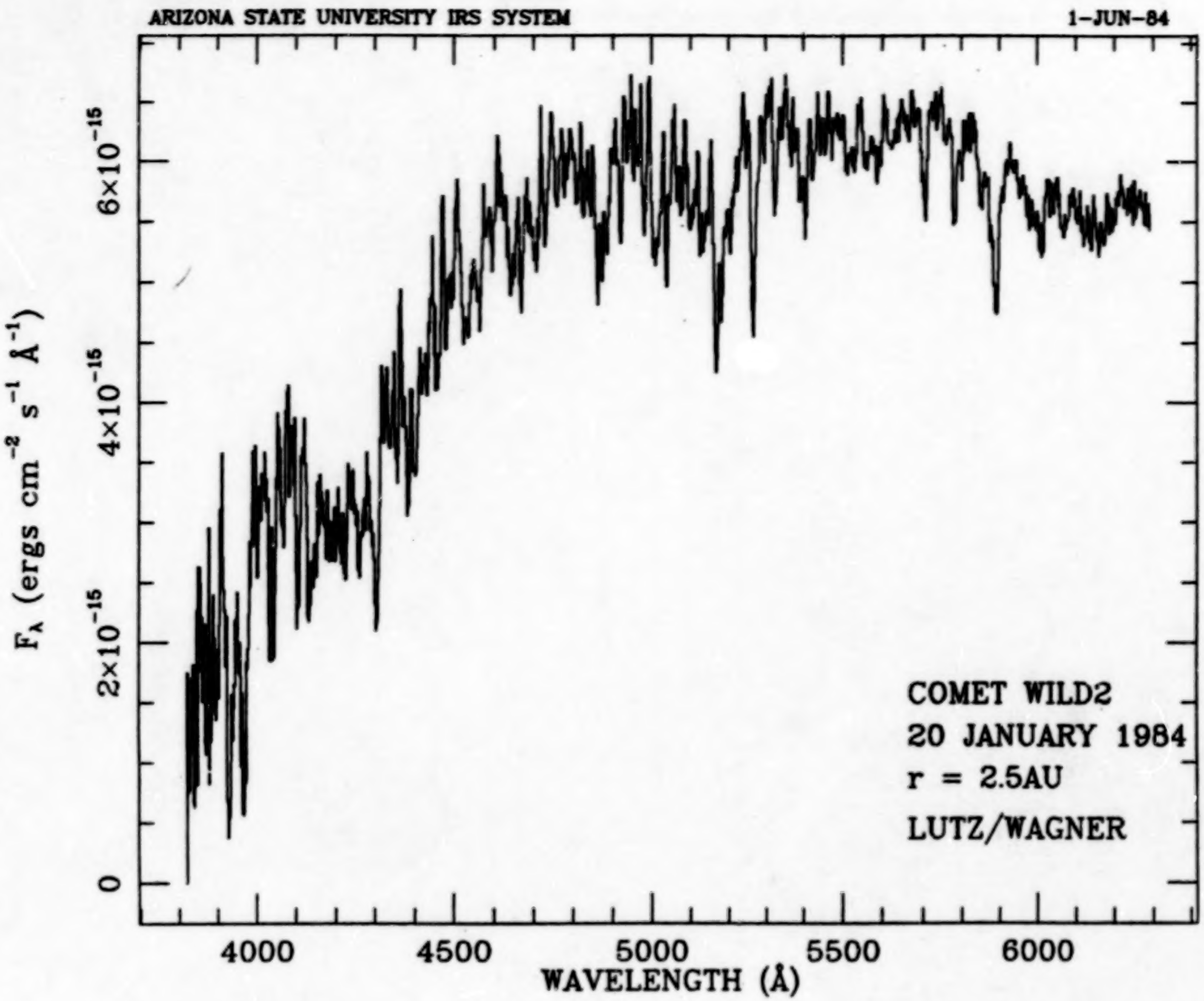

Figure 8. Spectrum of Comet Wild 2 obtained 20 January 1984 by B. Lutz and R. M. Wagner. This comet was at a heliocentric distance of 2.5 AU and is one of the comets chosen for study for the NASA Comet Rendezvous Mission (1990-1991).

P. A. Wehinger
S. Wyckoff
M. C. Festou
D. G. Schleicher
R. M. Wagner

REFERENCE

Eggen, O. J. and Sandage, A., 1964 Astrophys. J., 140, 130.

THE AMATEUR OBSERVATION NETWORK

With the publication of the IHW Amateur Observers' Manual by three American publishers and a Japanese publication of a translation, it is becoming possible to see just what level of participation amateur astronomers will have in the IHW. At present approximately 5% of the 2500-3000 Amateur Bulletin subscribers have obtained the Manual and returned the Observer Index form, registering them as participants in the network. The total number will increase as more Index forms trickle in and there will likely be a larger increase as Giacobini-Zinner and Halley approach in mid-1985.

The number of P/Crommelin observation reports has been minimal, partially due to the late arrival of ephemeris information in the Amateur Bulletin. It is also possible that amateurs found Crommelin observations to be more difficult than they anticipated. This will hopefully spur them on to more serious practice on their technique. For Halley amateurs will surely be more motivated and will not have ephemeris problems (if they have the Manual). For Giacobini-Zinner the problems surrounding the trial run will be corrected.

The Planetary Society has now printed and mailed two issues of the Amateur Bulletin. This experience has shown that the Bulletin must be prepared 2-3 months prior to its cover date to allow for on-time arrival. Slow publication and surface mail to overseas addressees necessitates the long lead time.

At present 23 countries are corresponding with the Lead Center regarding the collection of comet and meteor data. Ten meteor organizations in some of the same countries are participating in that category. Translations or adaptations of all or part of the Amateur Manual have been discussed for 13 languages.

S. J. Edberg

SOURCES OF INFORMATION

Stephen J. Edberg
International Halley Watch

The increasing interest of the public and amateur astronomers spawned by the approach of Comet Halley prompted the compilation of the following Handlist. This collection provides a quick and effective way of dealing with many requests for information of various types. I would like to encourage readers to develop their own lists apropos to their country and language and to forward a copy to the Pasadena Lead Center for publication in a future Newsletter. In this manner we can assist each other in satisfying the public demand for information.

A HANDLIST OF COMETARY AND ASTRONOMICAL INFORMATION SOURCES

Introduction

This collection of lists is designed to assist amateur astronomers at all levels and the general public in finding information on astronomy in general and comets in particular. Comet information is heavily biased towards Halley's Comet since it is even now drawing considerable interest as it approaches the inner solar system.

Books, periodicals, and articles covering various aspects of comets, general astronomy, astronomical observing, astrophotography, and telescopes are included. In addition, sources of slides, photographs, movies, and video imagery of various celestial objects are given. Finally, some organizations active in astronomy or space science are listed.

Books

The books listed here have been found to be very useful in their areas. They range from elementary to research-level and are available from the publisher listed or from local and mail order bookstores (which can also special order them). Check with the publisher or a bookstore for current prices. Hardcover and paperbound versions may both be available.

AAVSO Variable Star Atlas prepared by C. E. Scovil, American Association of Variable Star Observers, 187 Concord Avenue, Cambridge, MA 02138, USA or Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02238, USA; 1980. (This atlas includes *The "Sky and Telescope" Guide to the Heavens* listed below.)

A Complete Manual of Amateur Astronomy by P. C. Sherrod with T. L. Koed, Prentice-Hall, Inc., Englewood Cliffs, NJ 07632, USA; 1981. (This is an excellent introduction to many aspects of observational astronomy.)

All About Telescopes by Sam Brown (Publication E9094 or E9385), Edmund Scientific Co., 101 East Gloucester Pike, Barrington, NJ 08007, USA; 1981.

Amateur Astronomers Handbook, 4th ed., by J. B. Sidgwick, revised by J. Muirden, Enslow Publishers, Bloy St. and Ramsey Ave., Box 777, Hillside, NJ 07205, USA; 1980.

Astronomical Almanac, U. S. Naval Observatory, 34th and Massachusetts Ave., N.W., Washington, DC 20390, USA; issued annually.

Astronomical Calendar by G. Ottewell, c/o Department of Physics, Furman University, Greenville, SC 29613, USA; issued annually.

Astronomical Companion by G. Ottewell, c/o Department of Physics, Furman University, Greenville, SC 29613, USA; 1979.

Astronomical Photometry by A. A. Henden and R. H. Kaitchuck, Van Nostrand Reinhold Co., 135 West 50th St., New York, NY 10020, USA; 1982.

Astronomy, A Handbook by G. D. Roth, ed., translated and revised by A. Beer, Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02238, USA; 1975.

Astrophotography Basics (Publication AC-48), Eastman Kodak Co., Dept. 841, Rochester, NY 14650, USA; 1981.

BAA Handbook, British Astronomical Association, Burlington House, Piccadilly, London, W1V ONL, United Kingdom; issued annually.

Catalog of Cometary Orbits by B. G. Marsden; 1983. A staple bound version is available from the Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, MA 02138, USA. A "perfect" bound version is available from Enslow Publishers, Bloy St. and Ramsey Ave., Box 777, Hillside, NJ 07205, USA.

The Comet Halley Handbook by D. K. Yeomans with Z. Sekanina, NASA/JPL, available through stock number 033-000-00892-9 from Superintendent of Documents, U.S. Government Printing Office, Dept. 33, Washington, DC 20402, USA; 1983.

The Comet is Coming by Nigel Calder, Viking Press, 625 Madison Ave., New York, NY 10022, USA; 1980.

Comets by Laurel L. Wilkening, ed., Univ. of Arizona Press, P. O. Box 3398, Tucson, AZ 85722, USA; 1982. (This is an advanced level book.)

Comets, readings from *Scientific American*, by John C. Brandt, ed., W. H. Freeman & Co., 660 Market St., San Francisco, CA 94104, USA; 1981.

Comets: Vagabonds of Space by D. A. Seargent, Doubleday and Co., Inc., 501 Franklin Ave., Garden City, NY 11530, USA; 1982.

Halley: Comet 1986 by F. M. Branley, E. P. Dutton, Inc., 2 Park Avenue, New York, NY 10016, USA; 1983. (This is a children's-level book.)

International Halley Watch Amateur Observers' Manual for Scientific Comet Studies by S. J. Edberg, NASA/JPL and Enslow Publishers and Sky Publishing Corp; 1983. The NASA/JPL version is available in two parts, Part I. Methods, stock number 033-000-00888-1 and Part II. Ephemeris and Star Charts, stock number 033-000-00889-9 from Superintendent of Documents, U. S. Government Printing Office, Dept. 33, Washington, DC 20402, USA. Single volume versions containing both parts are available from Enslow Publishers, Bloy St. and Ramsey Ave., Box 777, Hillside, NJ 07205, USA, and from Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02238, USA. (This book is required reading for all amateur participants in the IHW.)

Introduction to Comets by J. C. Brandt & R. D. Chapman, Cambridge Univ. Press, 32 East 57th St., New York, NY 10022, USA; 1981. (This is a semi-advanced level book.)

Observational Astronomy for Amateurs, 4th ed., by J. B. Sidgwick, revised by J. Muirden, Enslow Publishers, Bloy St. and Ramsey Ave., Box 777, Hillside, NJ 07205, USA; 1982.

Photoelectric Photometry of Variable Stars by D. S. Hall & R. M. Genet, International Amateur-Professional Photoelectric Photometry assoc., c/o Robert C. Wolpert, Belmont Observatory, 144 Neptune Ave., North Babylon, NY 11704, USA; 1982.

Photography With Your Telescope by Sam Brown (Publication E9078), Edmund Scientific Co., 101 East Gloucester Pike, Barrington, NJ 08007, USA; 1980. (This booklet is a chapter in *All About Telescopes* above.)

Observer's Handbook, Royal Astronomical Society of Canada, 124 Merton St., Toronto, Ontario, M4S 2Z2, Canada; issued annually.

The "Sky and Telescope" Guide to the Heavens by L. J. Robinson, ed., Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02238, USA; 1980. (The two chapters on comets were also published in *Sky and Telescope*, Feb. 1981, p. 123, and Mar. 1981, p. 210.)

Sky Atlas 2000.0 by W. Tirion, Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02238, USA; 1981.

Sky Guide by T. Dickinson and S. Brown (Publication E9535), Edmund Scientific Co., 101 East Gloucester Pike, Barrington, NJ 08007, USA; 1977.

Skyshooting – Photography for Amateur Astronomers by R. N. Mayall & M. W. Mayall, Dover Publ., Inc., 180 Varick St., New York, NY 10014, USA; 1968.

Solar System Photometry Handbook by R. M. Genet, ed., Willman-Bell, Inc., P. O. Box 3125, Richmond, VA 23235, USA; 1983.

Starwatch by B. Mayer, Putnam-Perigee Publishing Group, 200 Madison Ave., New York, NY 10016, USA; 1984.

Articles

These articles provide good introductions to the topics in the titles. These sources can be found in libraries or back issues may be ordered from the address given in the list of periodicals.

"Backyard Photoelectric Photometry" in "Equipment Atlas" by R. M. Genet, *Astronomy*, February 1983, p. 51.

"Comets and How To Hunt Them" by J. E. Bortle, *Sky and Telescope*, February 1981, p. 123. (Reprinted in *The "Sky and Telescope" Guide to the Heavens*.)

"The Hairy Stars" by M. J. S. Belton, *Science Year, the World Book Science Annual*, 1983, p. 58.

"4 Probes to Comet Halley" by J. Eichenlaub, *Astronomy*, September 1983, p. 17.

"Halley Watch '86" by S. J. Edberg, *Astronomy*, March 1983, p. 18.

"Halley's Comet" by R. L. Newburn, Jr. and D. K. Yeomans, in *Annual Review of Earth and Planetary Sciences*, vol. 10, G. W. Wetherill, A. L. Albee, F. G. Stehli, eds.; 1982. (Available from Annual Reviews Inc., 4139 El Camino Way, Palo Alto, CA 94306, USA.)

Halley's Comet special issues of the *Journal of the British Interplanetary Society*, January and June 1984.

"Halley's Comet in 1986" by J. B. Tatum, *Mercury*, July-August 1982, p. 126.

"How to Observe Comets" by J. E. Bortle, *Sky and Telescope*, February 1981, p. 210. (Reprinted in *The "Sky and Telescope" Guide to the Heavens*.)

"Selecting Your First Telescope" by S. Harrington, *Mercury*, July-August 1982, p. 106. Also available in an information packet from the Astronomical Society of the Pacific.

"Waiting for Halley" in "Gazer's Gazette" by D. J. Eicher, *Astronomy*, June 1983, p. 35.

Periodicals

The publications listed below range from elementary to technical and single topic to broad spectrum. Write to the address listed for current subscription charges.

AAS Photobulletin, Robert J. Leacock, Subscription Manager, 211 Space Sciences Building, University of Florida, Gainesville, FL 32611, USA.

Astronomy, Astromedia Corp., 625 E. St. Paul Ave., P. O. Box 92788, Milwaukee, WI 53202, USA.

Comet News Service, P. O. Box TDR No. 92, Truckee, CA 95734, USA.

Griffith Observer, Griffith Observatory, 2800 East Observatory Rd., Los Angeles, CA 90027, USA.

Halley's Comet Watch Newsletter, 1 Smith Court, Box 188, Vincentown, NJ 08088, USA.

International Astronomical Union Circulars and *IAU Telegrams*, Central Bureau for Astronomical Telegrams, Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, MA 02138, USA.

International Comet Quarterly, Daniel Green, Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, MA 02138, USA. (Do not use "International Comet Quarterly" when addressing correspondence.)

International Halley Watch Amateur Observer's Bulletin, Planetary Society, P. O. Box 91687, Pasadena, CA 91109, USA.

Journal of the ALPO (The Strolling Astronomer), Association of Lunar and Planetary Observers, P. O. Box 3AZ, University Park, NM 88003, USA.

Mercury, Astronomical Society of the Pacific, 1290 24th Avenue, San Francisco, CA 94122, USA.

Meteor News, c/o Wanda Simmons, Route 3, Box 424-99, Callahan, FL 32011, USA.

The Minor Planet Bulletin, Derald D. Nye, Route 7 Box 511, Tucson, AZ 85747, USA.

Odyssey, Astromedia Corp., 625 E. St. Paul Ave., P. O. Box 92788, Milwaukee, WI 53202, USA. (A children's-level publication.)

Sky and Telescope, Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02238, USA.

Sky Calendar, Abrams Planetarium, Michigan State University, East Lansing, MI 48824-1324, USA.

Tonight's Asteroids, Dr. J. U. Gunter, 1411 North Mangum St., Durham, NC 27701, USA. (Enclose a self-addressed, stamped envelope for reply.)

Slides, Photographs, and Movies

The organizations listed here offer the items listed in brackets for sale. This list is not complete and the product listing may not be complete. Current prices, a complete description of their products, and ordering information may be obtained by writing to the organizations. Some of them charge for their catalogs.

Astro Cards, P. O. Box 35, Natrona Heights, PA 15065, USA [slides and videocassettes].

Astronomical Society of the Pacific, 1290 24th Ave., San Francisco, CA 94122, USA [slides and photographs].

California Institute of Technology Bookstore, 1-51, 1201 E. California Blvd., Pasadena, CA 91109, USA [slides and photographs].

The Center for Aerospace Education, Drew University, 36 Madison Ave., Madison, NJ 07940, USA [videodiscs].

Everything in the Universe, 5248 Lawton Ave., Oakland, CA 94618, USA [slides].

Foto-Kem Industries, Inc., 2800 W. Olive Ave., Burbank, CA 91505, USA [movies].

Hansen Planetarium, 15 South State St., Salt Lake City, UT 84111, USA [slides].

Holiday Film Corporation, 12607 E. Philadelphia St., Whittier, CA 90608, USA [slides and movies].

Hollywood Film Enterprises, 6060 Sunset Blvd., Hollywood, CA 90028, USA [movies].

Lick Observatory, University of California at Santa Cruz, Santa Cruz, CA 95064, USA [slides and photographs].

MMI Space Science Corp., 2303 N. Charles St., P. O. Box 19907, Baltimore, MD 21211, USA [slides and videocassettes].

Planetary Society, P. O. Box 91687, Pasadena, CA 91109, USA [slides].

Photographic Illustration Co., 2220 Magnolia Blvd., Burbank, CA 91506, USA [photographs].

Science Graphics, P. O. Box 17871, Tucson, AZ 85731, USA [slides].

Sky Publishing Corp., 49 Bay State Rd., Cambridge, MA 02238, USA [photographs].

Woodstock Products, P. O. Box 4087, Beverly Hills, CA 90213, USA [photographs].

Yerkes Observatory, Photographic Services, Williams Bay, WI 53191, USA [slides and photographs].

Organizations

Write to the address given for membership information. Membership in these groups often includes a subscription to their periodicals.

American Meteor Society, Dept. of Physics and Astronomy, State University of New York at Geneseo, Geneseo, NY 14454, USA.

American Association of Variable Star Observers (AAVSO), 187 Concord Ave., Cambridge, MA 02138, USA.

Association of Lunar and Planetary Observers (ALPO), P. O. Box 3AZ, University Park, NM 88003, USA.

Astronomical League, Don Archer, Executive Secretary, P. O. Box 12821, Tucson, AZ 85732, USA.

Astronomical Society of the Pacific (ASP), 1290 24th Ave., San Francisco, CA 94122, USA.

British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ, England.

Halley's Comet Watch '86, 1 Smith Court, Box 188, Vincentown, NJ 08088, USA.

International Amateur-Professional Photoelectric Photometry association (IAPPP), c/o R. C. Wolpert, Belmont Observatory, 144 Neptune Avenue, North Babylon, NY 11704, USA.

International Halley Watch, Jet Propulsion Laboratory, California Institute of Technology, T-1166SL, 4800 Oak Grove Drive, Pasadena, CA 91109, USA.

Planetary Society, P. O. Box 91687, Pasadena, CA 91109, USA.

Royal Astronomical Society of Canada, 124 Merton St., Toronto, Ontario, M4S 2Z2, Canada.

IHW
INTERNATIONAL
HALLEY WATCH

NASA
National Aeronautics and
Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL 400-213 5/84

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109

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INTERNATIONAL HALLEY WATCH DAYS

DATE 1983-85	AM PM	DEC deg	Δ AU	r AU	m1 mag	m2 mag	θ deg	β deg	MOON Ang deg	MOON Age days	Rationale	Obs
1983												
Oct.11	AM	+11	8.7	8.8		23.5	91	7	146	+5	Study activity	A,N,
12	AM	+11	8.7	8.8		23.5	92	7	157	+6	as a function	P,S
13	AM	+11	8.7	8.8		23.5	93	7	164	+7	of heliocentric distance (r) and phase angle (β).	
Dec. 9	AM	+10	7.5	8.4		23.1	152	3	149	+5	Study activity	A,N,
10	&	+10	7.5	8.4		23.1	154	3	132	+6	as a function	P,S
11	PM	+10	7.5	8.4		23.1	154	3	127	+7	of r and β .	
1984												
Jan.27	AM	+11	7.2	8.0		22.9	145	4	142	-5	Study activity	A,N,
28	&	+11	7.2	8.0		22.9	144	4	154	-4	as a function	P,S
29	PM	+11	7.2	8.0		22.9	143	4	163	-3	or r and β .	
Mar.23	PM	+12	7.6	7.6		22.9	87	8	162	-8	Study activity	A,N,
24	PM	+12	7.6	7.6		22.9	86	8	167	-7	as a function	P,S
25	PM	+12	7.6	7.6		22.9	85	8	161	-6	of r and β .	
Oct.29	AM	+12	5.4	5.9	17.7	21.6	115	9	164	+5	Study activity	A,N,
30	AM	+12	5.3	5.8	17.6	21.6	116	9	163	+6	as a function	P,S
31	AM	+12	5.3	5.8	17.6	21.6	117	9	154	+7	of r and β .	
Dec.21	AM	+12	4.4	5.4	16.8	21.0	169	2	156	-1	Study activity	A,N,
22	&	+12	4.4	5.4	16.8	21.0	169	2	164	0	as a function	P,S
23	PM	+12	4.4	5.4	16.8	21.0	168	2	163	+1	of r and β .	
1985												
Feb.13	PM	+13	4.4	4.9	16.3	20.8	112	11	162	-7	Study activity	A,N,
14	PM	+13	4.4	4.9	16.3	20.8	111	11	168	-6	as a function	P,S
15	PM	+13	4.4	4.9	16.3	20.8	110	11	162	-5	or r and β .	
Apr. 9	PM	+15	4.8	4.3	16.0	20.7	55	11	169	-11	Study activity	A,N,
10	PM	+15	4.8	4.3	16.0	20.7	54	11	167	-10	as a function	P,S
11	PM	+15	4.8	4.3	15.9	20.7	53	11	155	- 9	of r and β .	
Aug.24	AM	+19	3.2	2.8	13.0	18.9	59	18	158	+ 8	Study activity	A,N,
25	AM	+19	3.2	2.8	13.0	18.9	60	18	169	+ 9	as a function	P,S
26	AM	+19	3.2	2.8	12.9	18.8	61	18	169	+10	of r and β .	
Sep.21	AM	+20	2.4	2.5	11.7	17.9	84	24	165	+ 6	Study activity	A,N,
22	AM	+20	2.3	2.5	11.6	17.9	85	24	171	+ 7	as a function	P,S
23	AM	+20	2.3	2.5	11.6	17.8	86	24	162	+ 8	of r and β .	

DATE 1985-86	AM PM	DEC deg	Δ AU	r AU	m1 mag	m2 mag	θ deg	β deg	MOON Ang deg	MOON Age days	Rationale	Obs
1985												
Oct.18	AM	+21	1.5	2.1	10.0	16.6	115	25	166	+ 4	IR observations	A,N,
19	AM	+21	1.5	2.1	9.9	16.5	116	25	172	+ 5	of icy grains	P,S,
20	AM	+21	1.4	2.1	9.8	16.5	117	25	162	+ 6	begin.	I
Nov. 3	AM	+22	1.0	1.9	8.6	15.5	141	19	18	-10	Solar wind up-	A,N,
4	AM	+22	1.0	1.9	8.5	15.4	143	19	31	- 9	stream activity	P,S,
5	AM	+22	1.0	1.9	8.4	15.4	145	18	44	- 8	studied by ISEE	L,I
											s/c on Oct.31	
											now affects	
											comet Halley.	
Nov.12	AM	+22	0.8	1.8	7.7	14.8	162	10	152	- 1	Close Earth	A,N,
13	&	+22	0.8	1.8	7.6	14.8	164	9	169	0	approach. Sun-	P,S,
14	PM	+22	0.8	1.7	7.5	14.7	167	7	173	+ 1	Earth-Comet	L,I,
15		+22	0.7	1.7	7.4	14.6	170	6	156	+ 2	alignment for	R
16		+22	0.7	1.7	7.3	14.5	173	4	139	+ 3	observing out-	
17		+22	0.7	1.7	7.2	14.5	176	2	123	+ 4	of-plane tail	
18		+21	0.7	1.7	7.1	14.4	178	1	107	+ 5	phenomena.	
Dec. 8	PM	+ 8	0.7	1.4	6.3	14.0	108	43	162	- 4	Good phase	A,N,
9	PM	+ 7	0.7	1.4	6.2	14.1	105	44	147	- 3	angles for	P,S,
10	PM	+ 7	0.7	1.4	6.2	14.1	102	46	131	- 2	tail obser-	L,I,
11	PM	+ 6	0.8	1.3	6.2	14.1	99	47	114	- 1	vations.	R
12	PM	+ 5	0.8	1.3	6.2	14.1	97	48	97	0		
13	PM	+ 5	0.8	1.3	6.2	14.1	94	49	81	+ 1		
1986												
Jan. 4	PM	- 3	1.2	1.0	5.7	14.4	50	52	137	- 7	Study activity	A,N,
5	PM	- 3	1.2	1.0	5.7	14.4	49	52	123	- 6	as a function	P,S
6	PM	- 4	1.3	0.9	5.6	14.4	47	51	108	- 5	of r and β .	
Feb. 3	AM	- 9	1.6	0.6	4.0	14.0	8	13	84	- 6	Radio OH obser-	R.I
4	&	- 9	1.6	0.6	4.0	14.0	7	12	70	- 5	vations, IR	
5	PM	- 9	1.6	0.6	3.9	13.9	7	11	55	- 4	observations	
6		-10	1.6	0.6	3.9	13.9	7	11	41	- 3	possible near	
											perihelion.	
Feb.17	AM	-13	1.5	0.6	4.1	13.9	18	29	107	+ 8	Radio OH obser-	R,I
18	&	-13	1.5	0.6	4.2	13.9	19	31	119	+ 9	vations.	
19	PM	-13	1.5	0.6	4.2	13.9	20	33	132	+10		
Mar. 4	AM	-17	1.2	0.8	4.4	13.9	39	55	45	- 7		A,N,
5	AM	-18	1.2	0.8	4.4	13.9	41	57	31	- 6		P,S,
6	AM	-18	1.2	0.8	4.5	13.9	42	58	17	- 5	VEGA #1 s/c	L,I,
7	AM	-19	1.1	0.8	4.5	13.9	44	59	6	- 4	flyby.	R,G,
8	AM	-19	1.1	0.8	4.5	13.9	45	60	13	- 3	Planet A, MS-T5	PA,V
9	AM	-20	1.1	0.8	4.5	13.9	47	61	27	- 2	s/c flyby, VEGA	
10	AM	-20	1.1	0.8	4.5	13.9	48	62	40	- 1	#2 s/c flyby.	
11	AM	-20	1.0	0.9	4.5	13.8	50	62	54	0		

DATE 1986-87	AM PM	DEC deg	Δ AU	r AU	m1 mag	m2 mag	θ deg	β deg	MOON Ang deg	MOON Age days	Rationale	Obs
1986												
MAR.12	AM	-21	1.0	0.9	4.5	13.8	52	63	67	+ 1		A,N,
13	AM	-21	1.0	0.9	4.5	13.8	53	64	80	+ 2	Giotto s/c	P,S,
14	AM	-22	1.0	0.9	4.5	13.8	55	64	93	+ 3	flyby.	L,I,
15	AM	-23	0.9	0.9	4.5	13.8	57	65	105	+ 4		R,G,
16	AM	-23	0.9	0.9	4.5	13.7	58	65	118	+ 5		PA,V
17	AM	-24	0.9	1.0	4.5	13.7	60	66	131	+ 6		
18	AM	-24	0.9	1.0	4.5	13.7	62	66	143	+ 7		
Mar.28	AM	-34	0.6	1.1	4.2	13.3	84	63	71	-12	Solar wind up-	A,N,
29	AM	-35	0.6	1.1	4.2	13.2	87	62	55	-11	stream activity	P,S,
30	AM	-36	0.6	1.2	4.2	13.2	90	61	39	-10	studied by ISEE	L
											s/c on Mar.28	
											now affects	
											Comet Halley.	
Apr. 6	AM	-45	0.5	1.3	4.0	12.8	115	46	77	- 3	Close approach	A,N,
7	&	-46	0.4	1.3	3.9	12.8	119	44	93	- 2	to Earth; good	P,S,
8	PM	-47	0.4	1.3	3.9	12.8	123	41	108	- 1	viewing angle	L,I,
9		-47	0.4	1.3	3.9	12.8	127	38	123	0	for large scale	R
10		-47	0.4	1.3	4.0	12.8	132	35	137	+ 1	phenomena.	
11		-47	0.4	1.3	4.0	12.8	136	32	147	+ 2	Several possible	
12		-46	0.4	1.4	4.0	12.9	139	29	152	+ 3	stellar occulta-	
13		-45	0.4	1.4	4.1	12.9	142	27	148	+ 4	tions in April.	
May 3	PM	-17	0.9	1.7	6.3	14.9	125	30	148	- 6	Study activity	A,N,
4	PM	-16	0.9	1.7	6.4	15.0	124	30	154	- 5	as a function	P,S
5	PM	-15	0.9	1.7	6.5	15.1	122	30	153	- 4	of r and β .	
Jun. 1	PM	- 7	1.8	2.1	8.7	17.0	91	29	155	- 7	Study activity	A,N,
2	PM	- 6	1.8	2.1	8.7	17.0	90	29	146	- 6	as a function	P,S
3	PM	- 6	1.9	2.1	8.8	17.1	89	29	136	- 5	or r and β .	
Aug. 1	PM	- 6	3.6	2.9	11.2	19.1	40	13	92	- 5	Study activity	A,N,
2	PM	- 6	3.6	2.9	11.2	19.2	39	13	81	- 4	as a function	P,S
3	PM	- 6	3.6	2.9	11.3	19.2	38	13	70	- 3	of r and β .	
Nov.12	AM	-14	4.6	4.0	12.9	20.4	50	11	162	+10	Study activity	A,N,
13	AM	-14	4.6	4.0	12.9	20.4	51	11	162	+11	as a function	P,S
14	AM	-14	4.6	4.0	12.9	20.4	52	11	154	+12	of r and β .	
1987												
Jan. 6	AM	-16	4.2	4.6	13.2	20.5	106	12	155	+ 5	Study activity	A,N,
7	AM	-16	4.2	4.6	13.2	20.5	106	12	155	+ 6	as a function	P,S
8	AM	-16	4.2	4.6	13.2	20.5	107	12	146	+ 7	of r and β .	
Apr.22	PM	- 8	5.0	5.6	14.2	21.3	120	9	150	- 6	Study activity	A,N,
23	PM	- 7	5.0	5.6	14.2	21.3	119	9	156	- 5	as a function	P,S
24	PM	- 7	5.1	5.6	14.2	21.4	118	9	156	- 4	of r and β .	

DATE 1987	AM PM	DEC deg	Δ AU	R AU	m1 mag	m2 mag	θ deg	β deg	Ang deg	Age days	Rationale	Obs
Jun.16	PM	- 4	6.4	6.1		22.0	68	9	157	-10	Study activity	A,N
17	PM	- 4	6.4	6.1		22.0	67	9	160	- 9	as a function	P,S
18	PM	- 4	6.4	6.1		22.0	66	9	154	- 8	of r and β .	
Dec.27	AM	-10	7.2	7.6		22.8	110	7	156	+ 6	Study activity	A,N,
28	AM	-10	7.2	7.6		22.8	111	7	146	+ 7	as a function	P,S
29	AM	-10	7.2	7.6		22.8	112	7	135	+ 8	of r and β .	

Column	Table Entry
1	Calendar date (UT)
2	Morning object (AM) or Evening object (PM)
3	Declination (1950.0)
4	Δ = Geocentric distance of comet in AU
5	r = Heliocentric distance of comet in AU
6	m1 = estimated total visual magnitude
7	m2 = estimated nuclear magnitude with no activity
8	θ = Solar elongation angle (Sun-Earth-Comet angle)
9	β = Phase angle (Sun-Comet-Earth angle)
10	Moon angle (Moon-Earth-Comet angle)
11	Moon age in days (0 = new moon)
12	Rationale
13	International Halley Watch observing networks or flight projects that consider these observation intervals of considerable importance.

A = Astrometry Network
N = Near Nucleus Studies Network
P = Photometry and Polarimetry Network
S = Spectroscopy and Spectrophotometry Network
L = Large Scale Phenomena Network
I = Irafrared Spectroscopy and Radiometry Network
R = Radio Studies
G = Giotto Flight Project of European Space Agency
PA= Planet A and MS-T5 Flight Projects of Japan
V = Vega Flight Project of the Soviet Union

RECENT ORBITS OF COMETS HALLEY AND GIACOBINI-ZINNER

	Halley	Giacobini-Zinner
Recovery Date	1982 Oct. 16	1984 Apr. 3
Recovery Distance (r)	11.1 AU	4.6 AU
Recovery Magnitude	24.3 (Thaun-Gunn)	22.9 (R)
No. of Obs. to Date (Since Recovery)	44	6
Most Recent IHW Orbit No.	15	9
No. of Observations in Fit	653	82
Weighted Solution?	Yes	No
Obs. Interval in Fit	1835 Aug. 21 - 1984 Mar. 4	1972 Mar. 11 - 1984 Apr. 3
Mean Residual	2.3"	0.9"
Epoch (E. T.)	1986 Feb. 19.0	1985 Sept. 12.0
Perihelion Time (E. T.)	1986 Feb. 9.44410	1985 Sept. 5.25902
Perihelion Distance (AU)	0.5871023	1.0282631
Eccentricity	0.9672746	0.7075329
Arg. of Perihelion	111.84688	172.48970
Long. of Ascending Node	58.14415	194.70597
Inclination	162.23931	31.87830
A1	0.0935 E-08	-0.1408 E-08
A2	0.0155 E-08	-0.0439 E-08

Angles are in degrees and referred to the mean ecliptic and equinox of 1950. The nongravitational parameters (A1 and A2) are defined in a paper by Marsden, Sekanina, and Yeomans (1973). These orbital elements can be used to initialize ephemeris generation programs. The next issue of this Newsletter will include up to date ephemerides for both Comets Halley and Giacobini-Zinner. Observers who require more up to date ephemerides prior to the next Newletter are encouraged to contact D. K. Yeomans, Jet Propulsion Laboratory, Pasadena, California 91109, U. S. A. (Telephone 818-354-2127, Telex 675429 JPL COMM PSD).

D. K. Yeomans

REFERENCE

Marsden, B. G., Sekanina, Z., and Yeomans, D. K., 1973, A. J., 78, 211.

PREDICTIONS OF OCCULTATIONS OF STARS AND RADIO SOURCES
BY COMET HALLEY

E. Bowell and L. H. Wasserman
Lowell Observatory
P. O. Box 1269
Flagstaff, Arizona 86002
USA

The predictions presented here were made by comparing cometary ephemerides with star and radio-source catalogs and tagging all appulses for which the closest comet-source geocentric separation is smaller than a specified threshold.

The star catalog we used is the "Official IHW Preliminary Reference Star Catalog" supplied by R. S. Harrington. For predictions involving radio sources, we used the Master List of Radio Sources, updated from the version published by Dixon (1970). For our purposes, we discarded all duplicate entries in that catalog.

P/Halley's orbital elements are derived from 'orbit no. 12' by D. K. Yeomans. We have numerically integrated this orbit, computing perturbations by all nine planets in the usual way, and have included non-gravitational forces.

For occultations of stars we assumed a coma radius of 22,500 km (approximately a 1-arcmin diameter at 1 AU) and an appulse was logged if the minimum geocentric star-comet separations were less than the apparent angular radius of the comet plus twice the equatorial horizontal parallax, or 5 arcsec, whichever was greater. Radio-source occultations may involve cometary ion tails. Rather than attempt to model their extent and direction at this time, we have simply specified a very large cometary radius of 675,000 km (approximately a 30-arcmin diameter at 1 AU).

The accompanying tables list the predictions. For stars, star numbers are either BD or IHW sequence numbers (if no BD number pertains). The geocentric transverse velocity of the comet gives an indication of the duration of an event. 'Star to comet direction' indicates S when the comet is south of the star at the time of minimum geocentric separation, otherwise N for 'north.' Star coordinates are referred to the equator of 1950 and epoch of date, and magnitudes are B except for the stars marked with asterisks, where V is given. For some stars, minimum separations exceeding 100 arcsec are listed as asterisks. Quantities listed for occultations of radio sources follow the style of the Master List of Radio Sources, except that if the flux is tabulated as -1, no value was quoted in MLRS. Note that in the radio source catalog entries are not always strictly in chronological order.

We are not certain about the true ephemeris accuracy of P/Halley at present. However, runs of our appulse prediction program using different sets of recently derived orbital elements indicate substantial agreement among the lists of stars and the predicted geocentric circumstances. For example, predicted minimum geocentric separations have agreed to within 2 arcsec throughout the apparition, except for the time interval around perihelion and closest Earth approach (February through April 1986). Thus we are beginning to have some confidence that the predicted occultations of stars by P/Halley might actually happen. Accordingly, we have prepared maps of ground tracks (see Figures 1-4) for events

where we expect occultations of stars by the nuclear region of P/Halley to be visible from Earth. For each track, the date is located at the start of the 'path of totality' (it happens that all occultations plotted move westward on the Earth's surface). End points correspond to locations where the comet is on the horizon or the sun is less than 10 degrees below the horizon. For presentation purposes, we chose a coma diameter of 500 km. We will issue more detailed topocentric circumstances for these, and perhaps other, events when P/Halley's orbit becomes more certain.

The accuracy requirements for occultations of radio sources are far less stringent, so we expect the present list to remain essentially unchanged. We expect to update the stellar predictions whenever new (and more accurate) cometary orbits become available.

Those interested in receiving updated predictions, together with topocentric observing circumstances, are invited to get in touch with the authors or with D. K. Yeomans (Jet Propulsion Laboratory).

REFERENCE

Dixon, R. S., 1970, Astrophys. J. Suppl. Series, 20, (No. 180).

APPULSES BY P/HALLEY

START DATE: 1984 JUN 30.000

STAR NUMBER	MINIMUM SEPARATION (ARCSEC)	DATE (E.T.)	TRANSV VEL (KM/SEC)	STAR TO COMET DIRECTION	RA (1950.0) (EPOCH OF EVENT)	DEC	MAG	SOLAR ELONG
7095	2.8	1984 AUG 20.60490	16.6	S	6 39 39.061	13 40 28.30	13.80	48.2
6576	0.9	1984 NOV 24.53237	29.3	S	6 23 52.737	11 58 5.10	13.60	144.4
5890	10.1	1984 DEC 18.06287	35.7	N	6 0 58.109	11 55 21.33	13.70	167.7
5774	9.4	1984 DEC 21.76862	36.1	N	5 56 53.920	11 56 33.34	13.80	168.5
5303	7.8	1985 JAN 3.85055	35.7	N	5 42 14.009	12 4 22.47	13.20	159.4
4601	10.8	1985 JAN 27.10603	29.6	N	5 18 0.85[illegible]	12 31 31.69	14.10	132.1
3716	0.3	1985 MAR 17.92008	7.4	N	4 51 39.410	14 16 1.74	13.00	76.6
3925	8.0	1985 APR 27.79903	14.0	N	4 57 8.780	16 0 43.66	13.80	38.3
8290	7.3	1985 AUG 21.18163	11.9	S	6 3 41.234	19 11 39.45	13.30	56.8
+19 1264	17.3	1985 SEP 8.76896	5.6	S	6 11 10.401	19 29 0.13	8.90	72.9
8548	18.5	1985 SEP 29.67282	4.7	S	6 11 54.291	19 58 18.32	13.20	93.2
8481	17.7	1985 OCT 5.10289	7.6	S	6 9 41.234	20 9 52.41	13.60	99.0
8462	0.3	1985 OCT 6.14915	8.2	N	6 9 5.252	20 12 5.28	13.50	100.2
8427	16.0	1985 OCT 7.86252	9.3	N	6 7 58.689	20 16 8.66	13.40	102.1
8262	28.4	1985 OCT 13.60291	13.1	N	6 2 52.793	20 32 28.27	13.50	109.0
8207	13.3	1985 OCT 14.99930	13.[illegible]	N	6 1 15.849	20 37 16.12	12.70	110.8
8172	3.8	1985 OCT 15.89373	14.6	S	6 0 8.441	20 40 34.79	13.90	111.9
8149	26.7	1985 OCT 16.44739	15.1	S	5 59 24.644	20 42 52.68	12.70	112.6
8095	7.6	1985 OCT 17.63253	15.9	S	5 57 44.006	20 46 47.84	13.70	114.2
7705	6.0	1985 OCT 23.36545	20.9	N	5 46 18.564	21 11 25.80	14.10	123.1
7679	28.1	1985 OCT 24.16477	21.1	N	5 45 37.719	21 12 21.56	14.20	123.5
+21 0978	17.1	1985 OCT 25.26967	22.2	S	5 43 1.037	21 17 57.16	8.10	125.2
+21 0976	35.4	1985 OCT 25.29476	22.2	N	5 42 56.856	21 17 11.75	9.90	125.3
+21 0953	18.5	1985 OCT 25.91212	22.7	S	5 41 24.330	21 20 50.20	9.30	126.2
7551	23.5	1985 OCT 26.45853	23.3	N	5 39 58.452	21 22 35.84	13.80	127.1
+21 0892	41.9	1985 OCT 29.32465	25.9	N	5 31 36.509	21 35 22.46	9.00	131.9
+21 0772	22.3	1985 NOV 4.69686	32.8	S	5 6 26.099	22 3 38.56	9.20	144.1
+22 0775	37.1	1985 NOV 7.28503	35.9	S	4 52 55.159	22 11 36.00	9.70	149.8
+22 0756	29.4	1985 NOV 8.50540	37.3	S	4 45 45.157	22 13 42.01	9.50	152.7
+22 0754	31.3	1985 NOV 8.71565	37.6	N	4 44 27.727	22 12 57.27	9.00	153.2
+22 0722	34.9	1985 NOV 10.03433	39.3	N	4 35 59.565	22 13 37.67	10.00	156.5
+21 0648	44.0	1985 NOV 11.57546	41.0	S	4 25 13.338	22 13 21.38	8.90	160.5
+21 0642	54.2	1985 NOV 11.95961	41.5	N	4 22 23.342	22 10 50.30	4.40*	161.5
+21 0616	4.1	1985 NOV 12.96851	42.8	N	4 14 38.661	22 8 16.89	9.20	164.3
+20 0531	0.6	1985 NOV 19.59677	50.1	S	3 13 8.527	20 51 12.23	8.20	174.1
+20 0519	67.7	1985 NOV 20.03806	50.6	S	3 8 26.193	20 42 48.41	10.00	172.6
+19 0424	10.0	1985 NOV 22.12466	52.0	S	2 45 30.189	19 48 9.47	8.30	165.3
1511	2.7	1985 NOV 25.71176	53.2	N	2 4 21.497	17 42 4.39	11.10	151.8
+15 0252	19.5	1985 NOV 27.85449	52.8	N	1 39 48.199	16 9 13.94	10.40	143.6
+14 0228	26.4	1985 NOV 28.89435	52.4	N	1 28 8.324	15 20 47.60	9.00	139.6

STAR NUMBER	MINIMUM SEPARATION (ARCSEC)	DATE (E.T.)	TRANSV VEL (KM/SEC)	STAR TO COMET DIRECTION	RA (1950.0) (EPOCH OF EVENT)	DEC	MAG	SOLAR ELONG
+14 0202	20.4	1985 NOV 29.93024	51.9	S	1 16 45.156	14 31 50.93	9.30	135.7
+13 0174	77.1	1985 NOV 30.68747	51.3	S	1 8 36.708	13 55 44.64	11.10	132.9
+12 0114	8.2	1985 DEC 2.08083	50.2	N	0 54 11.129	12 45 31.69	10.00	127.8
+09 0046	12.9	1985 DEC 5.09276	47.2	S	0 25 24.438	10 18 17.32	10.60	117.3
+08 0029	54.3	1985 DEC 6.16595	46.0	S	0 16 1.313	9 28 9.24	10.80	113.8
+08 0004	26.1	1985 DEC 7.33134	44.6	S	0 6 23.612	8 34 13.83	10.60	110.1
+07 5123	51.9	1985 DEC 8.08310	43.7	N	0 0 29.961	7 59 33.78	8.20	107.7
+07 5113	46.7	1985 DEC 8.44797	43.2	N	23 57 42.179	7 43 43.56	8.70	106.6
+06 5207	3.3	1985 DEC 9.82843	41.5	N	23 47 35.098	6 46 9.04	9.10	102.5
+04 5023	30.4	1985 DEC 12.58199	38.4	S	23 29 31.955	5 0 15.41	9.90	94.9
+03 4861	44.8	1985 DEC 13.42622	37.2	S	23 24 31.092	4 30 29.17	10.40	92.8
+03 4855	34.8	1985 DEC 14.31512	36.3	N	23 19 31.368	3 58 58.96	11.40	90.5
+02 4637	23.2	1985 DEC 15.80052	34.6	N	23 11 38.502	3 11 28.65	10.40	86.9
+02 4634	17.1	1985 DEC 15.83792	34.6	N	23 11 26.937	3 10 24.95	9.90	86.8
+02 4634	54.2	1985 DEC 15.84977	34.6	N	23 11 24.255	3 9 28.71	10.40	86.8
+02 4631	26.5	1985 DEC 15.99830	34.6	N	23 10 38.498	3 5 20.55	10.10	86.4
+02 4624	54.5	1985 DEC 16.39572	34.1	N	23 8 40.376	2 52 52.21	7.80	85.5
+01 4677	46.6	1985 DEC 17.72612	32.7	S	23 2 18.012	2 15 51.37	10.30	82.4
- 1 4309	16.8	1985 DEC 26.38064	25.8	N	22 30 7.020	-1 1 56.62	10.40	65.0
-03 5403	3.8	1986 JAN 2.79992	22.2	S	22 10 43.515	-2 58 53.45	9.00	52.4
-20 5852	0.5	1986 MAR 9.86659	21.9	S	20 9 53.497	-19 54 53.84	9.00	48.2
-20 5831	46.1	1986 MAR 11.14173	22.3	N	20 7 11.292	-20 32 18.88	9.00	50.2
-2614460	19.2	1986 MAR 20.20067	27.8	S	19 41 28.862	-26 5 18.61	8.60	66.2
-2714128	23.7	1986 MAR 22.08755	29.5	S	19 33 51.757	-27 36 48.20	8.40	70.0
-3016902	27.1	1986 MAR 25.46740	33.4	S	19 16 43.528	-30 47 31.76	8.00	77.6
-3116470	42.5	1986 MAR 26.46130	34.7	S	19 10 32.854	-31 50 31.36	9.40	80.0
-3214940	45.5	1986 MAR 26.77502	35.0	S	19 8 28.086	-32 11 12.85	9.00	80.8
-3313913	59.8	1986 MAR 27.57079	36.1	S	19 2 52.624	-33 5 12.89	8.60	82.9
-3413279	52.0	1986 MAR 28.54462	37.6	S	18 55 23.104	-34 14 45.36	9.20	85.5
-3413276	41.1	1986 MAR 28.57259	37.6	S	18 55 9.983	-34 16 56.84	7.20	85.6
-3413269	15.7	1986 MAR 28.60760	37.9	N	18 54 55.550	-34 20 16.60	9.00	85.7
-3413225	42.1	1986 MAR 28.92002	38.2	S	18 52 17.061	-34 42 33.61	8.90	86.6
-3513008	61.4	1986 MAR 29.11030	38.6	S	18 50 38.632	-34 56 30.72	9.40	87.1
-3512991	75.7	1986 MAR 29.24277	38.9	S	18 49 28.837	-35 6 17.06	8.20	87.5
-3512981	1.0	1986 MAR 29.31488	38.9	S	18 48 54.287	-35 12 45.32	8.20	87.7
-3612976	71.6	1986 MAR 29.97652	39.9	S	18 42 47.037	-36 2 36.49	11.50*	89.6
-3712753	37.4	1986 MAR 30.73167	41.2	S	18 35 18.239	-37 2 44.56	9.00	91.9
-3812806	57.8	1986 MAR 31.70650	43.0	N	18 24 39.481	-38 23 19.78	7.90	95.0
-3812801	84.6	1986 MAR 31.77021	43.0	N	18 23 56.004	-38 28 57.85	8.90	95.2
-3812749	36.8	1986 APR 1.07950	43.7	S	18 20 9.170	-38 52 48.53	7.20	96.2

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STAR NUMBER	MINIMUM SEPARATION (ARCSEC)	DATE (E.T.)	TRANSV VEL (KM/SEC)	STAR TO COMET DIRECTION	RA (1950.0) (EPOCH OF EVENT)	DEC	MAG	SOLAR ELONG
-40 8393	64.1	1986 APR 2.49784	46.2	S	18 1 21.319	-40 50 49.67	9.00	101.1
-41 8416	55.5	1986 APR 2.96488	46.9	N	17 54 31.571	-41 31 29.69	8.70	102.8
-41 8347	89.5	1986 APR 3.22560	47.7	S	17 50 24.515	-41 50 52.06	8.70	103.8
-4112139	46.0	1986 APR 3.30084	47.7	N	17 49 18.602	-41 59 6.12	6.40	104.1
-42 7951	46.7	1986 APR 3.67091	48.4	N	17 43 19.839	-42 29 19.95	9.00	105.4
-4311901	58.1	1986 APR 4.13909	49.1	N	17 35 23.924	-43 7 1.14	7.30	107.2
-4311763	7.8	1986 APR 4.61424	50.2	S	17 26 51.916	-43 42 57.56	7.50	109.1
-4311684	41.7	1986 APR 4.85305	50.5	S	17 22 24.447	-44 0 28.35	9.50	110.0
-4411669	75.8	1986 APR 4.94823	50.5	S	17 20 35.286	-44 7 1.08	5.10	110.4
-45 8276	56.7	1986 APR 6.00051	52.5	S	16 59 27.178	-45 20 16.39	8.50	114.7
-45 8209	4.1	1986 APR 6.30077	52.8	N	16 53 1.990	-45 39 55.19	9.60	115.9
-45 8176	13.5	1986 APR 6.49764	53.1	S	16 48 42.163	-45 51 15.46	9.80	116.7
-4610930	25.8	1986 APR 6.98207	53.7	S	16 37 44.586	-46 17 21.01	8.10	118.8
-46 8126	86.6	1986 APR 6.99096	53.7	S	16 37 31.077	-46 16 48.70	9.50	118.8
-46 8059	31.9	1986 APR 7.31819	54.2	N	16 29 54.238	-46 34 25.31	8.50	120.2
-47 7360	50.0	1986 APR 9.19695	56.2	N	15 42 50.255	-47 25 56.84	9.00	128.2
-47 7194	115.7	1986 APR 9.72827	56.6	N	15 28 51.991	-47 27 44.78	8.50	130.4
-47 7170	99.6	1986 APR 9.79694	56.6	N	15 27 3.058	-47 27 5.28	9.00	130.7
-47 7247	107.5	1986 APR 9.56232	56.5	S	15 33 14.948	-47 24 30.82	8.50	129.7
-47 7060	33.7	1986 APR 10.16340	56.8	S	15 17 21.035	-47 20 54.09	9.20	132.2
-47 7052	100.6	1986 APR 10.17823	56.8	S	15 16 57.813	-47 19 33.69	8.50	132.2
-46 6895	21.4	1986 APR 11.75758	57.0	S	14 35 29.672	-46 27 0.59	9.60	138.3
-45 6861	7.1	1986 APR 12.13757	56.9	S	14 25 48.436	-46 5 52.16	9.00	139.6
-45 6796	43.2	1986 APR 12.42302	56.8	S	14 18 40.036	-45 47 15.11	8.50	140.6
-45 6769	116.0	1986 APR 12.56159	56.8	N	14 15 10.275	-45 40 28.55	8.50	141.1
-45 6740	77.6	1986 APR 12.76170	56.7	S	14 10 20.818	-45 23 13.50	9.90	141.7
-44 6651	110.0	1986 APR 12.97879	56.6	S	14 5 6.862	-45 6 32.26	9.90	142.4
-44 6616	10.5	1986 APR 13.24168	56.3	N	13 58 48.547	-44 47 44.93	9.50	143.2
-44 6572	65.0	1986 APR 13.50935	56.1	S	13 52 36.513	-44 24 17.91	8.00	143.9
-43 6246	75.6	1986 APR 14.11873	55.6	N	13 38 49.947	-43 31 48.78	9.60	145.5
-42 6280	2.7	1986 APR 14.72181	54.9	S	13 26 2.498	-42 31 48.00	9.60	146.8
-40 6068	39.3	1986 APR 15.65952	53.6	S	13 7 35.522	-40 52 50.90	8.50	148.3
-40 6059	103.3	1986 APR 15.72133	53.6	S	13 6 28.860	-40 45 11.09	8.00	148.4
-39 7937	75.1	1986 APR 16.39700	52.8	S	12 54 21.336	-39 30 54.74	7.70	149.0
-38 8069	24.6	1986 APR 16.59031	52.4	N	12 50 59.356	-39 10 38.61	9.20	149.1
-38 8062	28.2	1986 APR 16.62183	52.1	N	12 50 27.353	-39 7 8.45	6.90	149.2
-38 8056	65.4	1986 APR 16.65180	52.1	S	12 50 1.218	-39 2 24.77	8.00	149.2
-38 8043	20.4	1986 APR 16.69759	52.1	N	12 49 11.666	-38 58 28.82	9.10	149.2
-37 8042	15.2	1986 APR 17.42853	50.8	S	12 37 33.642	-37 34 57.96	7.50	149.4
-36 7949	85.7	1986 APR 17.71318	50.4	N	12 33 12.781	-37 3 56.80	9.30	149.4

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STAR NUMBER	MINIMUM SEPARATION (ARCSEC)	DATE (E.T.)	TRANSV VEL (KM/SEC)	STAR TO COMET DIRECTION	RA (1950.0) (EPOCH OF EVENT)	DEC	MAG	SOLAR ELONG
-35 7970	68.6	1986 APR 18.25168	49.4	N	12 25 32.156	-36 2 28.03	9.20	149.2
-34 8087	7.6	1986 APR 18.82197	48.3	N	12 17 58.398	-34 57 18.18	9.30	148.9
-34 8054	27.2	1986 APR 19.01284	47.9	S	12 15 34.213	-34 35 28.99	10.40	148.7
-33 8252	20.5	1986 APR 19.41609	47.2	S	12 10 36.903	-33 50 51.18	6.60	148.4
-32 8493	22.1	1986 APR 20.14575	46.1	S	12 2 15.618	-32 31 27.97	7.60	147.5
-30 9568	83.1	1986 APR 20.79197	45.0	S	11 55 30.482	-31 22 20.94	7.20	146.7
-25 8682	6.3	1986 APR 24.49723	38.1	N	11 25 8.642	-25 35 6.97	6.80	140.3
-17 3261	50.0	1986 MAY 1.08680	28.4	S	10 54 25.509	-18 13 31.19	8.80	128.4
-14 3181	41.4	1986 MAY 4.67228	24.2	N	10 44 30.673	-15 28 4.71	7.00	122.6
-14 3178	19.6	1986 MAY 4.88630	24.0	S	10 44 4.791	-15 18 44.86	9.00	122.3
-11 2913	19.8	1986 MAY 11.95998	17.6	N	10 32 28.290	-11 31 20.95	8.90	112.5

END DATE: 1987 JUL 1.000

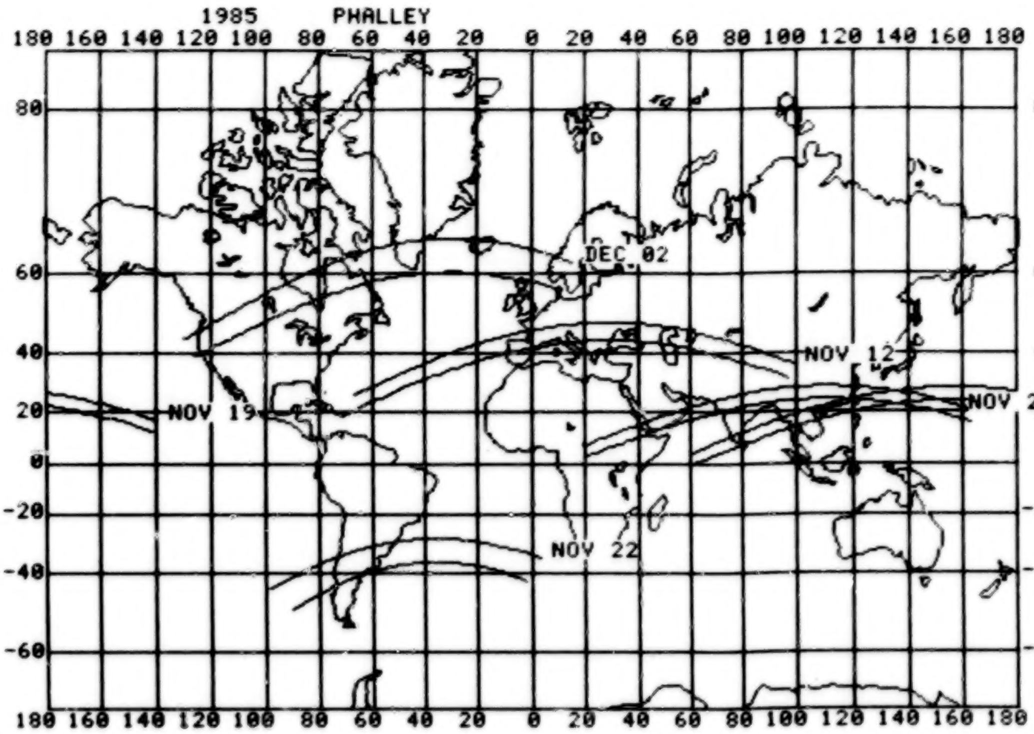

Figure 1

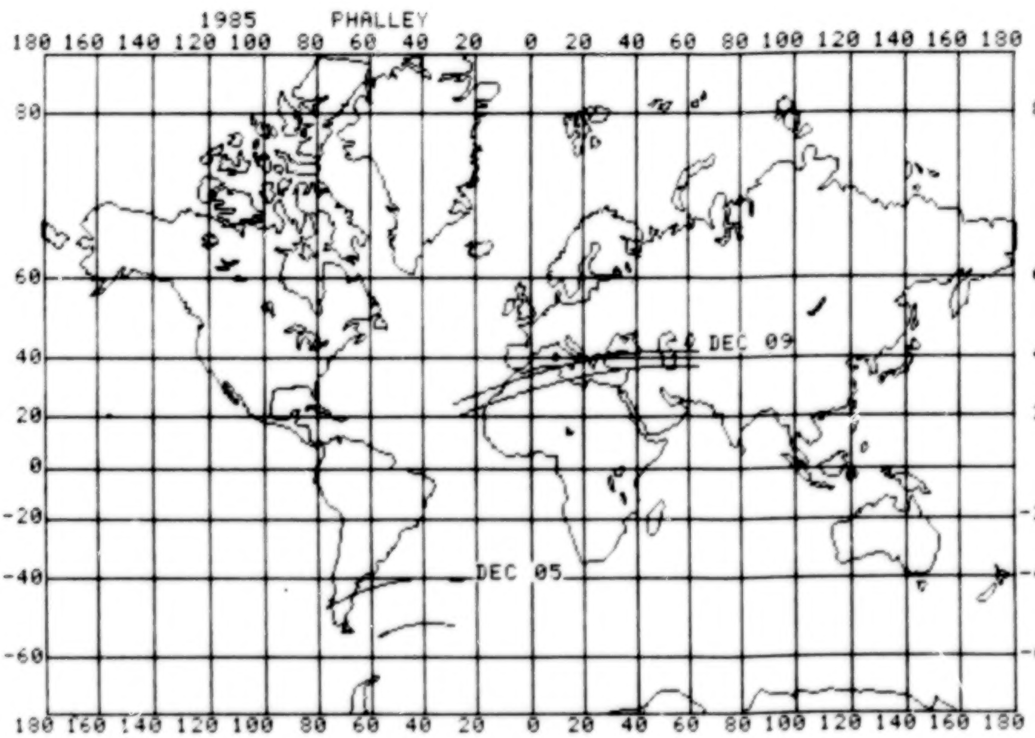

Figure 2

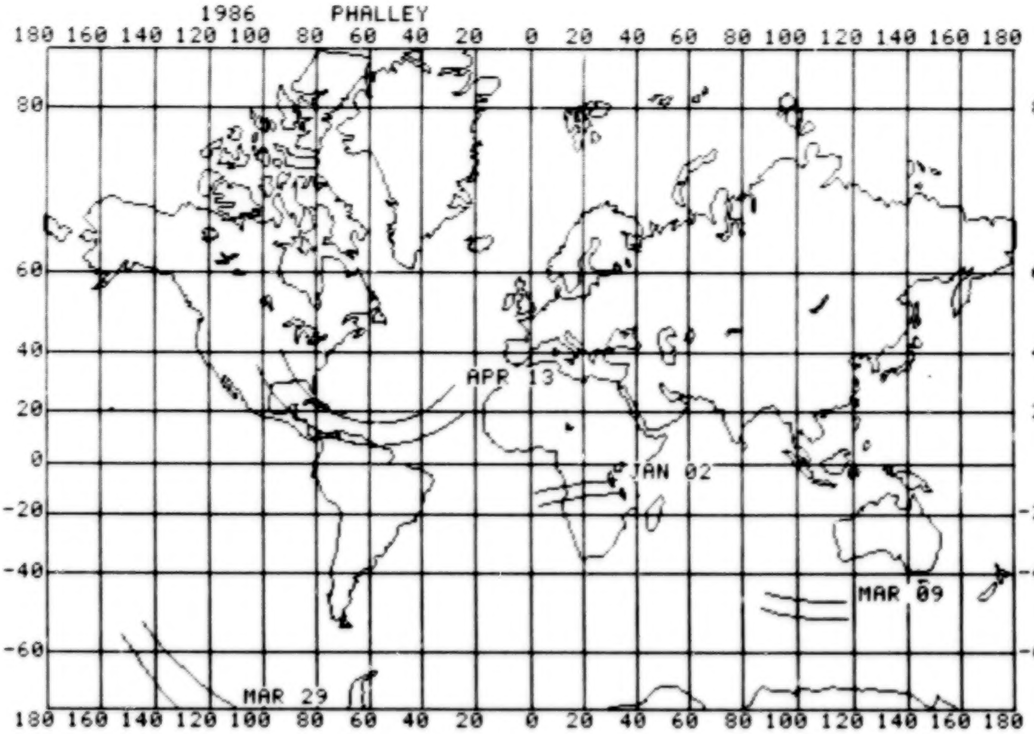

Figure 3

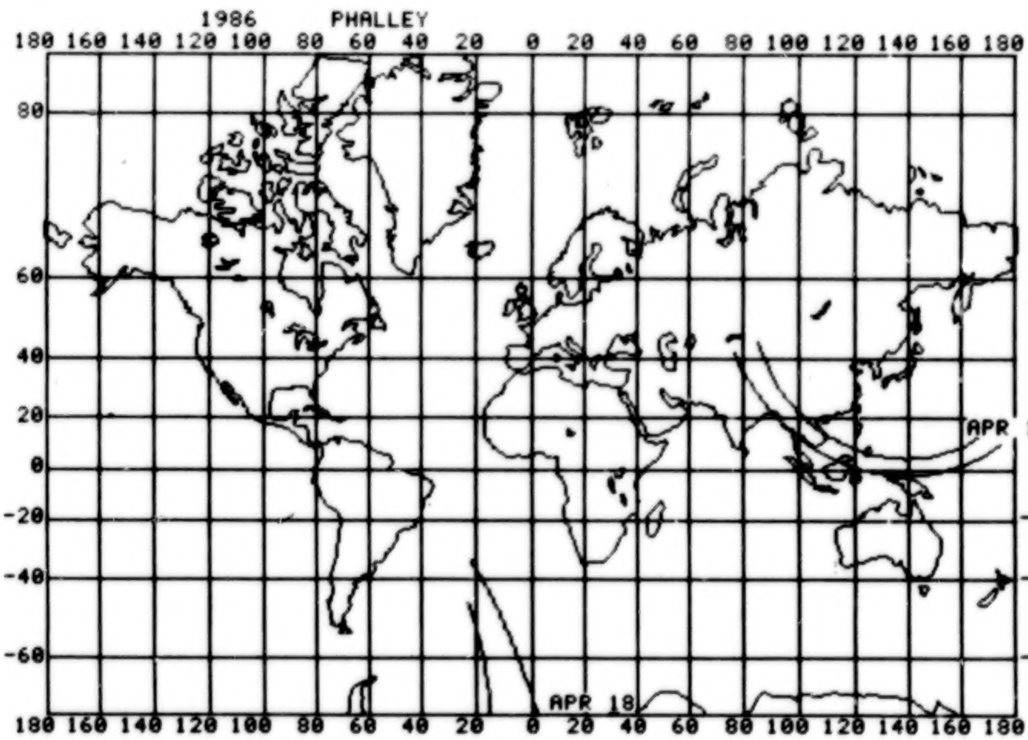

Figure 4

APPULSES BY P/HALLEY

START DATE: 1984 MAY 10.000

RADIO CATALOG SEARCH

SOURCE ID	MINIMUM SEP (ARCSEC)	SOURCE TO COMET DIRECTION	DATE (ET)	RA (1950.0)	DEC	SOLAR ELONG	FREQ (MHZ)	FLUX (JY)	SEQ NO
OH+119.5	26.0	S	1984 JUN 12.49347	6 11 43.000	13 59 0.00	15.0	1415	0.860	22809
OH+159.4	79.2	N	1984 AUG 8.85117	6 35 37.000	13 49 0.00	38.2	1415	0.200	24261
4C+13.34	44.2	N	1984 AUG 31.27297	6 42 39.300	13 28 54.00	57.6	179	2.900	24661
4CP13.34	87.8	S	1984 AUG 31.28032	6 42 42.000	13 31 0.00	57.6	178	3.500	24665
OH+156	134.6	N	1984 NOV 11.59163	6 33 20.000	12 4 0.00	129.7	1415	0.200	24124
OH+139.1	71.9	S	1984 NOV 25.12434	6 23 23.000	11 59 0.00	145.0	1415	0.190	23526
CC 198-02.2	164.1	S	1984 DEC 5.91465	6 13 34.200	11 57 27.00	157.1	408	2.620	22916
DCC198.3-02.2	77.0	S	1984 DEC 5.90187	6 13 35.000	11 56 0.00	157.1	2700	0.400	22917
4C+11.22	25.2	N	1984 DEC 5.88072	6 13 36.300	11 54 18.00	157.1	179	4.300	22921
4CP11.22	126.4	S	1984 DEC 6.08875	6 13 24.000	11 56 48.00	157.3	178	4.200	22889
OH+122	78.1	S	1984 DEC 6.05515	6 13 26.000	11 56 0.00	157.3	1415	0.590	22895
OG+127.7	113.1	S	1985 JAN 28.67515	5 16 36.000	12 36 0.00	130.2	1415	0.410	19634
4C+13.27	82.0	S	1985 MAR 10.89285	4 52 59.000	13 59 48.00	83.9	179	3.900	18296
OG+107	35.4	S	1985 MAY 14.12846	5 3 57.000	16 41 0.00	24.5	1415	0.740	18910
OG+125	113.6	S	1985 JUN 3.60292	5 14 53.000	17 27 0.00	8.8	1415	0.230	19515
H 0538+18	38.5	N	1985 JUL 10.51029	5 38 19.500	18 26 54.00	23.3	750	0.300	20949
H 0543+18	163.6	N	1985 JUL 17.84826	5 43 9.500	18 34 18.00	29.1	750	2.900	21266
OG+172	76.4	N	1985 JUL 18.06025	5 43 17.000	18 36 0.00	29.2	1415	0.340	21270
OG+174	142.7	S	1985 JUL 20.03011	5 44 32.000	18 42 0.00	30.8	1415	1.170	21322
4C+18.17	228.9	N	1985 JUL 20.06490	5 44 36.700	18 35 54.00	30.8	179	5.800	21327
DCC190.0+00.5	485.9	S	1985 OCT 9.98814	6 6 30.000	20 30 0.00	104.6	2700	28.000	22512
KLNS 13	427.6	S	1985 OCT 9.96864	6 6 30.000	20 29 0.00	104.6	3130	50.000	22511
PKS0606+20	503.1	S	1985 OCT 9.85260	6 6 37.000	20 29 54.00	104.5	635	23.000	22518
NRAO229	483.2	S	1985 OCT 9.77675	6 6 40.400	20 29 22.00	104.4	750	31.300	22532
W13	388.8	S	1985 OCT 10.53899	6 6 0.000	20 30 0.00	105.3	1390	70.000	22488
BGE 0606+20	466.3	S	1985 OCT 10.09555	6 6 24.000	20 30 0.00	104.7	408	44.200	22505
OH+201	309.3	N	1985 OCT 15.46787	6 0 37.000	20 34 0.00	111.4	1415	0.320	22124
OG+292	478.2	N	1985 OCT 19.02754	5 55 29.000	20 44 0.00	116.1	1415	0.300	21886
OG+275	319.1	N	1985 OCT 24.49640	5 44 49.000	21 9 0.00	124.0	1415	0.290	21341
OG+266	306.6	N	1985 OCT 26.47737	5 39 53.000	21 18 0.00	127.2	1415	0.380	21070
PP 0525+21	323.9	N	1985 OCT 31.14560	5 25 24.000	21 39 0.00	135.2	408G	1.500	20166
OG+236	303.3	S	1985 NOV 1.17954	5 21 37.000	21 54 0.00	137.1	1415	0.200	19908
OG+223	167.9	N	1985 NOV 3.00728	5 14 7.000	21 54 0.00	140.6	1415	0.530	19470
OF+294	872.8	S	1985 NOV 6.66727	4 56 23.000	22 24 0.00	148.4	1415	0.190	18505
OG+205	149.5	S	1985 NOV 5.34679	5 3 15.000	22 8 0.00	145.5	1415	0.370	18881
OF+284	953.5	N	1985 NOV 7.71107	4 50 27.000	21 56 0.00	150.8	1415	0.210	18152
PRF259	267.4	N	1985 NOV 7.05617	4 54 11.000	22 6 0.00	149.3	178	14.000	18387
OF+253	900.7	N	1985 NOV 10.63055	4 31 57.000	21 59 0.00	158.0	1415	0.320	17009
OF+260	227.9	S	1985 NOV 9.99824	4 36 14.000	22 18 0.00	155.4	1415	0.290	17245
VRO21.04.01	1027.9	N	1985 NOV 12.88963	4 15 19.000	21 51 42.00	164.1	610	1.400	15960
VRO21.04.02	1064.3	N	1985 NOV 12.21557	4 20 30.000	21 53 30.00	162.2	610	1.000	16250

VR021.03.02	1235.6	N	1985 NOV 15.47870	3 53 36.000	21 31 18.00	171.6	610	1.200	14644
4C+21.15	736.2	N	1985 NOV 15.42356	3 54 2.900	21 40 6.00	171.4	179	2.100	14668
OE+295	425.9	N	1985 NOV 15.10949	3 56 48.000	21 48 0.00	170.5	1415	0.240	14839
OE+233	886.8	N	1985 NOV 18.97243	3 19 49.000	20 49 0.00	176.0	1415	0.220	12674
PKS0322+21	538.9	S	1985 NOV 18.68727	3 22 32.000	21 17 42.00	176.8	635	1.600	12807
4C+21.11	511.8	S	1985 NOV 18.68473	3 22 33.800	21 17 18.00	176.8	179	2.700	12809
OE+237.7	848.6	S	1985 NOV 18.67632	3 22 36.000	21 23 0.00	176.9	1415	0.350	12811
AO 0322+21	571.7	S	1985 NOV 18.67378	3 22 40.000	21 18 29.00	176.9	430	0.700	12815
AO 0323+20	1021.2	N	1985 NOV 18.61169	3 23 32.000	20 53 20.00	177.0	430	0.800	12863
OE+250	977.3	N	1985 NOV 17.95476	3 30 9.000	21 5 0.00	177.7	1415	0.280	13282
AO 0336+21	265.3	N	1985 NOV 17.34788	3 36 2.000	21 25 48.00	177.0	430	1.100	13603
OE+260	93.5	S	1985 NOV 17.32965	3 36 10.000	21 32 0.00	176.9	1415	0.270	13607
AO 0337+21	1060.1	N	1985 NOV 17.22181	3 37 21.000	21 14 22.00	176.6	430	0.700	13676
OE+201	262.7	N	1985 NOV 20.61681	3 2 15.000	20 24 0.00	170.7	1415	0.190	11632
OE+202	1175.8	S	1985 NOV 20.58977	3 2 17.000	20 48 0.00	170.8	1415	0.250	11634
OD+275.8	844.9	S	1985 NOV 22.11067	2 45 29.000	20 2 0.00	165.3	1415	0.180	10669
OD+181	234.6	N	1985 NOV 21.85459	2 48 35.000	19 52 0.00	166.2	1415	0.200	10870
PKS0251+20	44.2	S	1985 NOV 21.62848	2 51 3.000	20 2 48.00	167.1	408	1.400	10974
3C074	789.7	N	1985 NOV 21.64363	2 51 3.000	19 49 0.00	167.0	159	8.500	10973
OD+185	432.1	N	1985 NOV 21.63414	2 51 5.000	19 55 0.00	167.0	1415	0.760	10978
VR019.02.04	159.1	N	1985 NOV 21.62619	2 51 7.000	19 59 36.00	167.1	610	1.800	10980
H 0251+20	81.6	S	1985 NOV 21.62121	2 51 7.400	20 3 36.00	167.1	750	1.300	10981
4C+20.11	47.4	S	1985 NOV 21.61944	2 51 9.000	20 3 6.00	167.1	179	5.000	10983
NRAO117	19.3	S	1985 NOV 21.61636	2 51 11.400	20 2 44.00	167.1	750	1.550	10987
OD+285	89.5	N	1985 NOV 21.61594	2 51 13.000	20 1 0.00	167.1	1415	0.810	10991
PRF113	102.0	N	1985 NOV 24.91170	2 13 38.000	18 12 0.00	154.8	178	6.500	8540
4C+17.11	1326.7	N	1985 NOV 24.92603	2 13 47.500	17 51 36.00	154.8	179	4.000	8549
PKS0213+17	1282.8	N	1985 NOV 24.91853	2 13 52.000	17 52 36.00	154.8	408	2.100	8557
H 0214+18	515.7	S	1985 NOV 24.81760	2 14 33.500	18 25 36.00	155.2	750	0.400	8620
H 0221+18	1158.2	N	1985 NOV 24.27842	2 21 12.800	18 18 30.00	157.2	750	0.300	9208
H 0222+18	288.1	N	1985 NOV 24.17905	2 22 8.300	18 36 12.00	157.6	750	0.300	9270
H 0224+19	821.2	S	1985 NOV 23.95682	2 24 25.300	19 2 6.00	158.5	750	0.400	9437
H 0225+18	149.9	N	1985 NOV 23.91893	2 25 5.900	18 47 42.00	158.6	750	0.500	9465
H 0227+19	760.3	S	1985 NOV 23.65258	2 27 56.300	19 11 42.00	159.6	750	1.700	9607
OD+149	1386.3	N	1985 NOV 23.56297	2 29 29.000	18 40 0.00	159.9	1415	0.480	9714
OD+153	1341.4	S	1985 NOV 23.29976	2 31 51.000	19 33 0.00	160.9	1415	0.210	9876
VR016.01.04	1343.2	N	1985 NOV 26.97774	1 50 11.000	16 27 6.00	146.9	610	1.200	7026
4C+16.04	1521.4	N	1985 NOV 26.97390	1 50 16.800	16 24 24.00	146.9	179	2.600	7033
OTL0150+16A	1397.9	N	1985 NOV 26.96983	1 50 17.400	16 26 33.90	147.0	327	1.100	7034
MC3 0150+164	1388.5	N	1985 NOV 26.96944	1 50 17.500	16 26 44.00	147.0	408	1.780	7035
OTL0150+16B	1399.9	N	1985 NOV 26.96910	1 50 17.930	16 26 33.90	147.0	327	0.800	7036
OC+184	797.9	N	1985 NOV 26.95196	1 50 19.000	16 37 0.00	147.0	1415	0.860	7038
CL0150+16	1222.8	N	1985 NOV 26.95568	1 50 24.000	16 30 0.00	147.0	26	36.000	7041
MC3 0150+165	1078.5	N	1985 NOV 26.93476	1 50 35.800	16 33 14.00	147.1	408	0.920	7051
VR016.01.05	276.0	S	1985 NOV 26.89654	1 50 38.000	16 56 42.00	147.2	610	1.100	7053
OTL0208+183	1405.4	S	1985 NOV 25.33761	2 8 17.880	18 19 51.10	153.2	327	0.800	8068
4C+18.08	1154.2	S	1985 NOV 25.29918	2 8 48.700	18 17 18.00	153.4	179	2.200	8112
OD+115.2	780.7	S	1985 NOV 25.28018	2 9 8.000	18 12 0.00	153.4	1415	0.180	8137
OTL0209+181	615.6	S	1985 NOV 25.26496	2 9 21.260	18 9 55.50	153.5	327	0.700	8154
MC3 0128+152	532.6	N	1985 NOV 28.83999	1 28 54.300	15 15 21.00	139.8	408	0.530	5821
OC+152	138.6	N	1985 NOV 28.59739	1 31 29.000	15 33 0.00	140.7	1415	0.360	6018

MC3 0131+154	447.5	N	1985	NOV	28.60512	1 31 29.700	15 27 44.00	140.7	408	0.720	6019
MC3 0131+159	1197.3	S	1985	NOV	28.54084	1 31 41.500	15 56 52.00	141.0	408	0.660	6034
WE 0132+15W1	950.3	N	1985	NOV	28.54720	1 32 18.080	15 22 27.20	140.9	1415	0.077	6068
WE 0132+15W2	1483.4	N	1985	NOV	28.52847	1 32 40.740	15 14 51.20	141.0	1415	0.127	6108
MC3 0132+152	1464.9	N	1985	NOV	28.52771	1 32 40.900	15 15 11.00	141.0	408	0.480	6109
WE 0133+15W1	512.1	N	1985	NOV	28.39605	1 33 51.300	15 36 27.30	141.5	1415	0.009	6171
WE 0134+15W2	1034.6	N	1985	NOV	28.37372	1 34 16.180	15 29 10.60	141.6	1415	0.007	6209
WE 0135+15W1	1307.9	N	1985	NOV	28.31242	1 35 2.570	15 27 39.70	141.8	1415	0.023	6260
MC3 0137+159	438.5	N	1985	NOV	28.03806	1 37 51.500	15 54 9.00	142.9	408	0.340	6387
MC3 0138+161	149.7	S	1985	NOV	27.93307	1 38 51.700	16 8 21.00	143.3	408	0.580	6451
OC+167.2	21.3	S	1985	NOV	27.80803	1 40 19.000	16 12 0.00	143.8	1415	0.230	6542
OC+169	1278.8	N	1985	NOV	27.72412	1 41 40.000	15 55 0.00	144.1	1415	0.370	6616
MC3 0141+158	1487.1	N	1985	NOV	27.71151	1 41 52.400	15 52 14.00	144.1	408	0.930	6626
MC3 0146+170	1468.5	S	1985	NOV	27.20842	1 46 42.200	17 2 9.00	146.0	408	0.300	6824
CL0106+13	1422.3	N	1985	NOV	30.96368	1 6 12.000	13 19 0.00	131.9	26	222.000	4355
OC+112.4	357.1	S	1985	NOV	30.78995	1 7 26.000	13 55 0.00	132.5	1415	0.450	4457
OC+124	1082.7	N	1985	NOV	30.16957	1 14 32.000	14 3 0.00	134.8	1415	0.570	4920
OC+132	191.8	N	1985	NOV	29.69309	1 19 24.000	14 40 0.00	136.6	1415	0.180	5215
OC+136	755.8	S	1985	NOV	29.48332	1 21 23.000	15 5 0.00	137.4	1415	0.190	5352
OB+176	382.7	N	1985	DEC	2.96352	0 45 32.000	11 56 0.00	124.6	1415	0.580	3064
4C+11.07	937.1	N	1985	DEC	2.98405	0 45 32.200	11 46 18.00	124.6	179	2.400	3065
MC2 0045+118	816.4	N	1985	DEC	2.97813	0 45 33.000	11 48 29.00	124.6	408	1.620	3067
4CP11.07	489.3	N	1985	DEC	2.96412	0 45 34.000	11 54 18.00	124.6	178	3.800	3068
PKS0045+11	778.5	N	1985	DEC	2.97158	0 45 36.000	11 49 24.00	124.6	408	1.200	3071
4C+12.07	1306.1	S	1985	DEC	2.35108	0 50 59.100	12 52 42.00	126.8	179	4.200	3394
4CP12.07	1268.9	S	1985	DEC	2.33932	0 51 7.000	12 52 42.00	126.9	178	4.900	3406
MC2 0026+105	676.6	S	1985	DEC	4.95367	0 26 24.500	10 35 24.00	117.8	408	0.470	1549
OB+145	744.3	S	1985	DEC	4.94242	0 26 29.000	10 37 0.00	117.8	1415	0.240	1552
MC2 0027+106	580.7	S	1985	DEC	4.78980	0 27 55.400	10 41 46.00	118.3	408	1.150	1628
MC2 0029+110	1298.4	S	1985	DEC	4.56943	0 29 39.400	11 3 39.00	119.1	408	0.390	1730
MC2 0033+110	8.8	N	1985	DEC	4.21051	0 33 28.200	11 0 35.00	120.3	408	0.380	1997
OB+158	721.0	N	1985	DEC	4.11644	0 34 37.000	10 54 0.00	120.6	1415	0.230	2103
4CP11.06	627.3	S	1985	DEC	3.30767	0 41 48.000	11 54 48.00	123.4	178	2.600	2789
OB+169	187.2	N	1985	DEC	3.32862	0 41 54.000	11 41 0.00	123.4	1415	0.340	2799
4C+11.06	698.0	S	1985	DEC	3.28753	0 41 58.100	11 56 54.00	123.5	179	2.600	2809
MC2 0041+119	569.4	S	1985	DEC	3.29127	0 41 58.800	11 54 42.00	123.5	408	1.840	2810
OB+020	1204.3	N	1985	DEC	6.67371	0 12 15.000	8 45 0.00	112.1	1415	0.510	717
OB+027	946.2	N	1985	DEC	6.15568	0 16 30.000	9 13 0.00	113.8	1415	0.590	966
MC2 0024+012	50.8	S	1985	DEC	5.21152	0 24 19.800	10 13 11.00	116.9	408	0.750	1437
4CP10.00A	126.5	S	1985	DEC	5.16476	0 24 43.000	10 16 36.00	117.1	178	2.300	1454
MC2 0026+103	181.3	N	1985	DEC	5.00503	0 26 15.700	10 19 25.00	117.6	408	0.470	1545
OZ+097	1271.0	S	1985	DEC	8.24383	23 58 44.000	8 13 0.00	107.2	1415	0.500	84492
OZ+067	583.7	S	1985	DEC	10.95438	23 39 39.000	6 10 0.00	99.4	1415	0.320	83522
OZ+076	1399.2	N	1985	DEC	10.14231	23 45 57.000	6 12 0.00	101.6	1415	0.720	83778
4C+06.76	1421.2	N	1985	DEC	10.14142	23 45 57.900	6 11 42.00	101.6	179	3.100	83786
4C+06.77	248.7	N	1985	DEC	9.85262	23 47 30.800	6 41 24.00	102.5	179	3.400	83854
OZ+079	51.5	N	1985	DEC	9.83855	23 47 32.000	6 45 0.00	102.5	1415	0.500	83856
PKS 2350+069	533.1	N	1985	DEC	9.39580	23 50 53.000	6 55 55.00	103.8	2700	0.360	84033
OZ+085	703.4	N	1985	DEC	9.40296	23 50 54.000	6 53 0.00	103.8	1415	0.320	84035
4CP06.77	610.3	N	1985	DEC	9.36774	23 51 7.000	6 55 54.00	103.9	178	3.000	84039
OZ+051.4	130.1	S	1985	DEC	12.35670	23 30 52.000	5 10 0.00	95.5	1415	0.190	83061

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OZ+057	638.7	N	1985	DEC	11.87516	23 34 11.000	5 16 0.00	96.8	1415	0.380	83210
MSH 23+010	212.1	S	1985	DEC	11.61314	23 35 30.000	5 39 0.00	97.5	85	13.000	83280
OZ+044	1019.0	N	1985	DEC	13.34161	23 25 27.000	4 17 0.00	93.0	1415	0.720	82772
4C+04.79	647.6	N	1985	DEC	13.30253	23 25 31.400	4 24 6.00	93.1	179	2.400	82783
PKS2325+04	745.8	N	1985	DEC	13.30780	23 25 32.000	4 22 24.00	93.1	408	3.700	82784
MSH 22+012	906.7	N	1985	DEC	20.28529	22 51 42.000	0 54 0.00	76.9	85	13.000	81065
GC2256+01	498.8	S	1985	DEC	19.02334	22 56 21.000	1 47 37.00	79.6	5000	0.270	81316
PKS2256+017	473.0	S	1985	DEC	19.01261	22 56 24.400	1 47 30.00	79.6	2700	0.360	81319
OY+070	135.6	N	1985	DEC	22.87926	22 41 36.000	0 6 0.00	71.6	1415	0.260	80508
OY-043	584.4	N	1985	DEC	27.97714	22 25 42.000	-1 39 0.00	62.2	1415	0.280	79660
PRF845	681.8	N	1985	DEC	29.51595	22 21 32.000	-2 6 0.00	59.5	178	26.000	79442
MSH 22-004	117.2	S	1986	JAN	5.05577	22 5 42.000	-3 27 0.00	48.8	85	13.000	78658
PKS2156-04	129.5	S	1986	JAN	9.48381	21 56 44.000	-4 20 24.00	41.9	1410	0.600	78207
OX-095	21.0	N	1986	JAN	9.50744	21 56 45.000	-4 23 0.00	41.9	1415	0.710	78208
4C-04.83	338.4	N	1986	JAN	9.55907	21 56 46.900	-4 28 30.00	41.8	179	4.400	78209
OX-098	221.3	S	1986	JAN	8.45456	21 58 42.000	-4 7 0.00	43.5	1415	0.550	78291
OX-054	517.3	S	1986	JAN	23.29170	21 31 50.000	-6 45 0.00	21.8	1415	0.290	77020
OX-056	75.2	N	1986	JAN	22.46697	21 33 32.000	-6 45 0.00	23.0	1415	0.320	77095
OX-051	200.9	N	1986	JAN	24.10012	21 30 44.000	-7 5 0.00	20.7	1415	0.380	76974
OX-102	496.4	S	1986	FEB	9.22114	21 1 10.000	-10 22 0.00	7.9	1415	0.190	75579
MSH 20-103	607.9	N	1986	MAR	4.20465	20 21 18.000	-17 38 0.00	39.5	85	8.500	73548
OW-123	590.8	S	1986	MAR	7.73510	20 13 44.000	-18 50 0.00	44.9	1415	0.230	73109
OW-125	224.3	N	1986	MAR	7.42943	20 14 59.000	-18 52 0.00	44.4	1415	0.160	73172
OW-201	561.4	S	1986	MAR	13.78564	20 0 30.000	-21 48 0.00	54.6	1415	0.210	72499
OTL1952-236	153.5	S	1986	MAR	16.79725	19 52 40.660	-23 40 31.40	59.8	327	0.500	72175
OV-289	823.5	S	1986	MAR	16.44444	19 53 9.000	-23 19 0.00	59.1	1415	0.210	72212
OTL1945-250	311.5	S	1986	MAR	18.93976	19 45 44.850	-25 5 37.20	63.7	327	0.800	71865
OV-283	218.8	N	1986	MAR	17.76061	19 50 3.000	-24 23 0.00	61.5	1415	0.410	72061
OV-249.6	1059.4	S	1986	MAR	22.81878	19 29 44.000	-28 2 0.00	71.6	1415	1.040	71134
OV-253.4	595.8	N	1986	MAR	22.61690	19 32 1.000	-28 12 0.00	71.1	1415	0.230	71237
OV-261.3	1187.6	N	1986	MAR	21.63770	19 36 47.000	-27 29 0.00	69.1	1415	0.230	71444
OV-315	1186.0	N	1986	MAR	26.83013	19 9 6.000	-32 31 0.00	80.9	1415	0.270	69929
OV-306	398.4	N	1986	MAR	27.49469	19 3 48.000	-33 6 0.00	82.7	1415	0.200	69604
MSH 18-308	1355.7	S	1986	MAR	29.13527	18 49 24.000	-34 41 0.00	87.2	85	17.000	68788
FJ 1817-39	797.8	S	1986	APR	1.29423	18 17 0.000	-39 0 0.00	97.0	30	42.000	66862
MSH 18-303	86.0	N	1986	APR	1.27744	18 17 48.000	-39 11 0.00	96.9	85	41.000	66913
MSH 18-304	50.6	S	1986	MAR	31.57508	18 26 6.000	-38 11 0.00	94.6	85	18.000	67424
MSH 17-408	101.4	N	1986	APR	2.97498	17 54 24.000	-41 33 0.00	102.9	85	30.000	65579
MSH 18-302	1474.2	S	1986	APR	2.03503	18 6 54.000	-39 52 0.00	99.5	85	9.000	66278
CC 341-01.9	1803.2	S	1986	APR	5.98976	16 58 57.200	-44 51 35.00	114.6	408	0.820	62542
CC 341-02.7	696.6	N	1986	APR	5.92155	17 1 28.400	-45 27 8.00	114.3	408	0.950	62679
MSH 17-403	1801.7	S	1986	APR	5.22441	17 14 24.000	-44 0 0.00	111.5	85	18.000	63365
CC 334+01.9	1862.1	N	1986	APR	7.94294	16 15 14.200	-47 28 58.00	122.8	408	0.700	60005
CC 335+01.6	1816.0	N	1986	APR	7.81868	16 18 17.700	-47 23 52.00	122.3	408	0.680	60219
SG 336.8+00.6	1987.1	N	1986	APR	7.40693	16 28 21.900	-47 10 8.00	120.6	408L	9.700	60814
TD 337.3+01.0	343.7	S	1986	APR	7.35569	16 28 54.000	-46 30 0.00	120.3	2650	5.000	60851
ADG337.3+01.0	387.6	S	1986	APR	7.35374	16 28 56.000	-46 29 12.00	120.3	5000	10.000	60853
BM 337.3+01.0	332.6	S	1986	APR	7.35161	16 29 0.000	-46 30 0.00	120.3	1410	8.100	60859
AJG 049	353.0	S	1986	APR	7.34784	16 29 5.000	-46 29 30.00	120.3	408	24.600	60863
AG G337.3+1.0	351.1	S	1986	APR	7.34716	16 29 6.000	-46 29 30.00	120.3	408	-1.000	60866
DKM337.3+01.0	351.1	S	1986	APR	7.34716	16 29 6.000	-46 29 30.00	120.3	1000	15.000	60865

KES40	351.1	S	1986	APR	7.34716	16	29	6.000	-46	29	30.00	120.3	408	18.000	60864
AG G338.1-0.0	769.8	N	1986	APR	7.14412	16	34	14.000	-46	38	16.00	119.4	408	-1.000	61105
GS 337.6-00.0	1977.5	N	1986	APR	7.14939	16	34	30.000	-46	58	6.00	119.5	5000L	169.000	61121
SG 337.6-00.0	1937.9	N	1986	APR	7.14786	16	34	31.400	-46	57	23.00	119.5	408L	350.000	61122
AJG 051	460.8	S	1986	APR	7.10861	16	34	40.000	-46	16	35.00	119.3	408	7.000	61136
SG 338.2+00.4	455.9	S	1986	APR	7.10731	16	34	41.900	-46	16	36.00	119.3	408	1.900	61138
AG G338.2+0.4	455.7	S	1986	APR	7.10725	16	34	42.000	-46	16	36.00	119.3	408	-1.000	61139
ADG337.7-00.1	1846.6	N	1986	APR	7.12921	16	34	56.000	-46	55	0.00	119.4	5000	15.000	61151
AJG 050	1762.0	N	1986	APR	7.11458	16	35	15.000	-46	52	55.00	119.3	408	30.000	61174
AG G337.8-0.1	1761.0	N	1986	APR	7.11457	16	35	15.000	-46	52	54.00	119.3	408	-1.000	61173
TD 337.8-00.1	1707.7	N	1986	APR	7.11382	16	35	15.000	-46	52	0.00	119.3	2650	35.000	61172
SG 337.8-00.1	1761.4	N	1986	APR	7.11443	16	35	15.200	-46	52	54.00	119.3	408	26.000	61175
GS 337.8-00.1	1728.0	N	1986	APR	7.10915	16	35	22.000	-46	52	6.00	119.3	5000L	169.000	61183
DKM337.8-00.1	1716.1	N	1986	APR	7.10898	16	35	22.000	-46	51	54.00	119.3	1000	15.000	61182
KES41	1716.1	N	1986	APR	7.10898	16	35	22.000	-46	51	54.00	119.3	408	17.000	61181
GS 338.1+00.0	867.4	N	1986	APR	7.07143	16	35	58.000	-46	36	18.00	119.1	5000L	169.000	61222
BM 338.0-00.1	1396.7	N	1986	APR	7.07394	16	36	5.000	-46	45	0.00	119.2	1410	9.600	61234
TD 338.0-00.1	1164.2	N	1986	APR	7.06921	16	36	7.000	-46	41	0.00	119.1	2650	50.000	61237
SG 338.0-00.1	1357.7	N	1986	APR	7.06918	16	36	10.900	-46	44	8.00	119.1	408L	25.000	61240
ADG338.0-00.1	1326.4	N	1986	APR	7.06867	16	36	11.000	-46	43	36.00	119.1	5000	73.000	61241
GS 338.0-00.1	1433.2	N	1986	APR	7.06805	16	36	14.000	-46	45	18.00	119.1	5000L	169.000	61244
MSH 16-407	595.8	N	1986	APR	7.05328	16	36	18.000	-46	31	0.00	119.1	85	330.000	61251
GM 28	259.8	S	1986	APR	7.03461	16	36	27.000	-46	16	12.00	119.0	5000	25.800	61270
SG 338.4+00.2	223.2	S	1986	APR	7.03506	16	36	27.100	-46	16	49.00	119.0	408	12.000	61271
GS 338.4+00.2	263.6	S	1986	APR	7.03384	16	36	28.000	-46	16	6.00	119.0	5000L	169.000	61272
KOM39	554.1	N	1986	APR	7.04352	16	36	31.000	-46	30	0.00	119.0	408	185.000	61276
KES43	231.5	S	1986	APR	7.03142	16	36	32.000	-46	16	30.00	119.0	408	11.000	61278
CTB 34	954.7	N	1986	APR	7.03694	16	36	48.000	-46	36	0.00	119.0	960	185.000	61295
GS 338.1-00.2	1324.6	N	1986	APR	7.03511	16	36	58.000	-46	41	54.00	119.0	5000L	169.000	61304
SG 338.1-00.2	1306.8	N	1986	APR	7.03386	16	36	59.400	-46	41	33.00	119.0	408L	25.000	61306
TD 338.4+00.1	74.8	S	1986	APR	7.01063	16	37	4.000	-46	18	0.00	118.9	2650	95.000	61309
ADG338.4+00.1	157.4	S	1986	APR	7.00943	16	37	4.000	-46	16	36.00	118.9	5000	54.000	61308
GM 29	97.9	S	1986	APR	7.00813	16	37	7.000	-46	17	30.00	118.9	5000	52.300	61311
SG 338.4+00.0	2.1	N	1986	APR	7.00871	16	37	8.200	-46	19	9.00	118.9	408L	40.000	61312
GS 338.4+00.1	44.2	S	1986	APR	7.00675	16	37	10.000	-46	18	18.00	118.9	5000L	169.000	61319
BM 338.4+00.1	180.0	S	1986	APR	7.00478	16	37	10.000	-46	16	0.00	118.9	1410	31.000	61318
KES44	21.7	S	1986	APR	7.00347	16	37	15.000	-46	18	30.00	118.9	408	12.000	61322
AJG 053	360.3	S	1986	APR	6.99495	16	37	20.000	-46	12	35.00	118.8	408	37.000	61328
AG G338.5+0.1	357.1	S	1986	APR	6.99428	16	37	21.000	-46	12	36.00	118.8	408	-1.000	61330
SG 338.5+00.1	356.9	S	1986	APR	6.99421	16	37	21.100	-46	12	36.00	118.8	408L	40.000	61331
AJG 052	536.1	N	1986	APR	7.00437	16	37	25.000	-46	27	35.00	118.9	408	20.000	61335
SG 338.3-00.1	542.1	N	1986	APR	7.00309	16	37	26.900	-46	27	37.00	118.9	408L	40.000	61338
AG G338.3-0.1	542.3	N	1986	APR	7.00302	16	37	27.000	-46	27	37.00	118.9	408	-1.000	61340
TD 338.4-00.2	714.4	N	1986	APR	6.97533	16	38	9.000	-46	29	0.00	118.7	2650	-1.000	61378
GS 338.4-00.2	756.3	N	1986	APR	6.97378	16	38	12.000	-46	29	36.00	118.7	5000L	169.000	61380
SG 338.4-00.2	736.0	N	1986	APR	6.97305	16	38	12.600	-46	29	14.00	118.7	408	1.800	61381
CC 338+00.3	801.6	N	1986	APR	6.95227	16	38	42.800	-46	29	14.00	118.6	408	1.900	61417
SG 338.5-00.3	801.6	N	1986	APR	6.95227	16	38	42.800	-46	29	14.00	118.6	408L	350.000	61416
CC 338-00.5	1663.2	N	1986	APR	6.93497	16	39	24.700	-46	42	17.00	118.6	408	1.620	61451
SG 338.9-00.1	776.9	S	1986	APR	6.89048	16	39	35.400	-46	0	29.00	118.4	408	3.900	61456
TD 338.9-00.1	745.1	S	1986	APR	6.89052	16	39	36.000	-46	1	0.00	118.4	2650	3.000	61459

GS 338.9-00.1	756.9	S	1986	APR	6.89034	16	39	36.000	-46	0	48.00	118.4	5000	3.000	61458
BM 339.0-00.1	761.4	S	1986	APR	6.87640	16	39	55.000	-46	0	0.00	118.3	1410	-1.000	61475
CC 339-00.2	969.5	S	1986	APR	6.81781	16	41	10.600	-45	53	33.00	118.1	408	0.670	61520
PSR 1641-45	969.5	S	1986	APR	6.81781	16	41	10.600	-45	53	33.00	118.1	400	1.319	61519
BM 339.1-00.4	357.9	S	1986	APR	6.80941	16	41	35.000	-46	3	0.00	118.0	1410	-1.000	61563
TD 339.1-00.4	299.1	S	1986	APR	6.81033	16	41	35.000	-46	4	0.00	118.0	2650	4.000	61564
AJG 054	298.9	S	1986	APR	6.79933	16	41	50.000	-46	3	25.00	118.0	408	7.500	61587
AG G339.2-0.4	296.3	S	1986	APR	6.79791	16	41	52.000	-46	3	23.00	118.0	408	-1.000	61588
AG G340.0-0.5	1563.9	S	1986	APR	6.61489	16	45	31.000	-45	32	54.00	117.2	408	-1.000	61805
TD 339.5-01.3	1780.9	N	1986	APR	6.59979	16	47	7.000	-46	26	0.00	117.2	2650	-1.000	61869
TD 340.4-01.0	1099.9	S	1986	APR	6.44992	16	49	20.000	-45	31	0.00	116.5	2650	-1.000	62017
SG 340.8-01.0	1961.1	S	1986	APR	6.37405	16	50	39.000	-45	12	42.00	116.2	408L	11.700	62084
GS 340.8-01.0	1990.2	S	1986	APR	6.37352	16	50	39.000	-45	12	12.00	116.2	5000	17.000	62083
TD 340.8-01.0	1988.7	S	1986	APR	6.36970	16	50	44.000	-45	12	0.00	116.2	2650	18.000	62089
BM 340.8-01.0	1914.7	S	1986	APR	6.36643	16	50	50.000	-45	13	0.00	116.2	1410	21.000	62099
MSH 14-409	728.5	N	1986	APR	11.38223	14	45	0.000	-46	57	0.00	136.9	85	33.000	54856
MILN01	264.0	N	1986	APR	11.38205	14	45	8.000	-46	49	36.00	136.9	2700	0.500	54864
PKS1445-46	260.6	N	1986	APR	11.38081	14	45	10.000	-46	49	36.00	136.9	408	8.700	54870
PKS1346-438	838.2	S	1986	APR	13.77488	13	46	58.200	-43	49	7.00	144.6	2700	0.250	51311
PKS1349-439	976.4	S	1986	APR	13.64910	13	49	52.900	-43	58	1.00	144.3	2700	0.540	51492
PKS1353-440	1493.9	S	1986	APR	13.51959	13	53	5.900	-44	1	3.00	143.9	2700	0.290	51683
PKS1307-403	1721.4	S	1986	APR	15.73264	13	7	19.900	-40	20	8.00	148.4	2700	0.320	48967
MSH 13-402	1494.8	N	1986	APR	14.85435	13	22	24.000	-42	41	0.00	147.0	85	8700.000	49835
PKS1322-42	1714.4	N	1986	APR	14.84772	13	22	24.000	-42	45	0.00	147.0	408	-1.000	49834
CTA 59	1729.0	N	1986	APR	14.84403	13	22	28.000	-42	45	36.00	147.0	960	462.000	49836
PKS1322-42	1846.2	N	1986	APR	14.83401	13	22	36.000	-43	48	24.00	147.0	2700	128.000	49844
PKS1231-374	2062.6	N	1986	APR	17.76401	12	31	3.000	-37	25	8.00	149.4	2700	0.170	46175
PKS1231-362	1672.5	S	1986	APR	17.91762	12	31	30.200	-36	16	47.00	149.4	2700	0.210	46194
PKS1248-385	989.0	S	1986	APR	16.80146	12	48	10.600	-38	32	25.00	149.3	2700	0.200	47302
PKS1300-405	1172.0	N	1986	APR	16.00573	13	0	24.100	-40	32	32.00	148.7	2700	0.160	48443
MSH 12-302	2076.2	N	1986	APR	19.72976	12	5	24.000	-33	43	0.00	148.0	85	17.000	44600
PKS1206-337	1929.8	N	1986	APR	19.68172	12	6	3.700	-33	46	26.00	148.1	2700	0.480	44624
OH-310	1634.1	N	1986	APR	19.69716	12	6	6.000	-33	41	0.00	148.1	1415	0.870	44628
PKS1211-338	381.9	S	1986	APR	19.36235	12	11	31.300	-33	52	9.00	148.4	2700	0.420	44977
OH-319	426.3	S	1986	APR	19.35853	12	11	36.000	-33	52	0.00	148.4	1415	0.800	44986
OH-322	150.7	S	1986	APR	19.21874	12	13	6.000	-34	11	0.00	148.6	1415	0.220	45087
B1 1146-29	904.3	S	1986	APR	21.79805	11	46	37.200	-29	30	0.00	145.1	408	1.200	43365
OM-278	418.0	S	1986	APR	21.73842	11	46	45.000	-29	42	0.00	145.2	1415	0.220	43372
MSH 11-209	1120.8	S	1986	APR	21.46679	11	49	48.000	-30	0	0.00	145.6	85	7.000	43537
B1 1150-30	867.9	S	1986	APR	21.41922	11	50	2.200	-30	8	0.00	145.7	408	1.200	43546
OM-383	595.9	S	1986	APR	21.39408	11	50	3.000	-30	14	0.00	145.7	1415	0.240	43547
MSH 11-315	281.4	N	1986	APR	20.76400	11	55	30.000	-31	30	0.00	146.7	85	13.000	43936
OM-394	297.7	S	1986	APR	20.71183	11	56	30.000	-31	28	0.00	146.8	1415	0.820	43996
PKS1156-313	532.6	S	1986	APR	20.72977	11	56	30.400	-31	23	6.00	146.7	2700	0.340	43997
HM 1156-31	63.9	N	1986	APR	20.67988	11	56	32.100	-31	36	0.00	146.8	408	1.900	44001
B1S1128-26	1117.5	N	1986	APR	23.85192	11	28	36.000	-26	44	0.00	141.5	408	1.000	42185
MSH 11-206	1101.0	N	1986	APR	23.71163	11	29	36.000	-26	56	0.00	141.7	85	8.000	42230
HM 1131-27	1297.8	N	1986	APR	23.49017	11	31	1.900	-27	18	0.00	142.1	408	2.200	42313
B1S1131-27	545.0	N	1986	APR	23.57732	11	31	1.900	-27	1	0.00	142.0	408	2.200	42312
PKS 1131-269	452.5	N	1986	APR	23.58464	11	31	3.400	-26	59	13.00	142.0	2700	0.190	42314
B1 1131-26	348.1	N	1986	APR	23.59519	11	31	4.100	-26	57	0.00	141.9	408	2.000	42315

OM-252	346.5	N	1986	APR	23.56105	11	31	19.000	-27	0	0.00	142.0	1415	0.350	42345
B1 1132-27	1474.1	N	1986	APR	23.22612	11	32	51.100	-27	44	0.00	142.6	408	1.200	42463
B1S1132-27	392.1	N	1986	APR	23.34356	11	32	52.700	-27	20	0.00	142.4	408	0.800	42465
B1 1136-28	1225.7	N	1986	APR	22.83526	11	36	5.700	-28	17	0.00	143.3	408	1.000	42633
QL42	547.0	N	1986	APR	22.60671	11	38	30.000	-28	30	0.00	143.7	240	11.500	42796
MSH 11-208	285.6	N	1986	APR	22.57211	11	39	0.000	-28	30	0.00	143.8	85	27.000	42840
FJ 1139-28	1068.4	S	1986	APR	22.71122	11	39	0.000	-28	0	0.00	143.5	30	52.000	42834
PKS 1139-28	454.4	N	1986	APR	22.54736	11	39	3.700	-28	34	27.00	143.8	2700	1.360	42850
HM 1139-28	449.5	N	1986	APR	22.54724	11	39	4.000	-28	34	24.00	143.8	408	6.700	42857
OM-265	431.4	N	1986	APR	22.54908	11	39	4.000	-28	34	0.00	143.8	1415	2.780	42856
PKS1139-28	417.9	N	1986	APR	22.55046	11	39	4.000	-28	33	42.00	143.8	408	8.000	42853
B1 1139-28	686.0	N	1986	APR	2[illegible].51932	11	39	5.900	-28	40	0.00	143.9	408	6.300	42858
HM 1117-24	1414.9	N	1986	APR	25.51142	11	17	40.800	-24	30	0.00	138.4	408	3.100	41549
PKS 1126-258	48.8	N	1986	APR	24.28135	11	26	32.000	-25	53	44.00	140.7	2700	0.180	42035
HM 1126-25	473.0	S	1986	APR	24.34556	11	26	32.800	-25	42	0.00	140.5	408	2.300	42038
B1 1126-25	225.2	S	1986	APR	24.31000	11	26	34.400	-25	48	0.00	140.6	408	1.500	42040
OM-244	682.6	S	1986	APR	24.33902	11	26	46.000	-25	40	0.00	140.6	1415	0.200	42059
B1 1129-26	1279.6	S	1986	APR	24.01625	11	29	26.300	-26	0	0.00	141.2	408	1.000	42228
OM-212.7	834.6	N	1986	APR	27.53103	11	7	36.000	-21	56	0.00	134.6	1415	0.210	40862
MC1 1107-218	545.0	N	1986	APR	27.55304	11	7	44.700	-21	51	11.00	134.6	408	1.000	40880
OM-214	1475.7	S	1986	APR	27.68686	11	8	51.000	-21	19	0.00	134.3	1415	0.190	40966
MC1 1109-216	958.7	S	1986	APR	27.44954	11	9	30.800	-21	40	51.00	134.8	408	0.560	41017
B1 1109-22	49.7	S	1986	APR	27.26442	11	9	37.300	-22	4	0.00	135.1	408	1.200	41030
MC1 1109-220	112.3	S	1986	APR	27.27447	11	9	37.600	-22	2	35.00	135.1	408	0.740	41031
OM-216.1	98.8	S	1986	APR	27.27069	11	9	38.000	-22	3	0.00	135.1	1415	0.240	41032
PKS 1109-220	115.1	S	1986	APR	27.27012	11	9	39.000	-22	2	51.00	135.1	2700	0.260	41037
MC1 1110-220	451.5	S	1986	APR	27.25184	11	10	1.500	-22	0	13.00	135.1	408	0.230	41081
OM-217	1179.9	N	1986	APR	26.95295	11	10	6.000	-22	40	0.00	135.7	1415	0.350	41082
OM-218	1481.0	S	1986	APR	27.38781	11	10	15.000	-21	39	0.00	134.9	1415	1.370	41089
HM 1110-22	606.0	N	1986	APR	27.00026	11	10	21.300	-22	30	0.00	135.6	408	2.200	41095
PKS 1110-217	1406.2	S	1986	APR	27.35205	11	10	21.400	-21	42	18.00	134.9	2700	0.940	41096
MC1 1110-217	1417.3	S	1986	APR	27.35333	11	10	21.600	-21	42	5.00	134.9	408	2.500	41098
PKS 1110-217	1415.5	S	1986	APR	27.35266	11	10	21.700	-21	42	9.00	134.9	2700	0.940	41099
MC1 1111-220	1238.6	S	1986	APR	27.05383	11	11	39.700	-22	4	49.00	135.5	408	0.340	41195
MC1 1112-221	1411.2	S	1986	APR	26.99458	11	12	6.100	-22	6	57.00	135.6	408	0.170	41250
MC1 1059-199	891.2	N	1986	APR	29.44677	10	59	25.000	-19	55	16.00	131.2	408	0.290	40162
MC1 1100-200A	784.2	N	1986	APR	29.31689	11	0	0.600	-20	1	47.00	131.4	408	0.490	40236
MC1 1100-200B	609.2	N	1986	APR	29.28863	11	0	16.200	-20	1	31.00	131.5	408	0.240	40249
MSH 11-202	801.7	N	1986	APR	28.50286	11	3	18.000	-20	52	0.00	132.9	85	16.000	40478
OM-207	471.8	N	1986	APR	28.42795	11	3	54.000	-20	53	0.00	133.0	1415	1.920	40530
PKS 1103-20	456.2	N	1986	APR	28.42833	11	3	54.700	-20	52	48.00	133.0	2700	1.390	40531
HM 1103-20	454.2	N	1986	APR	28.42797	11	3	54.900	-20	52	48.00	133.0	408	7.000	40533
PKS1103-20	453.1	N	1986	APR	28.42778	11	3	55.000	-20	52	48.00	133.0	408	5.900	40534
MC1 1103-208	452.5	N	1986	APR	28.42713	11	3	55.200	-20	52	50.00	133.0	408	8.400	40537
B1 1103-20	453.2	N	1986	APR	28.42463	11	3	55.800	-20	53	0.00	133.0	408	6.200	40538
MC1 1104-205	830.3	S	1986	APR	28.54798	11	4	30.300	-20	30	41.00	132.8	408	0.310	40590
PKS 1056-185	443.0	S	1986	APR	30.59999	10	56	23.500	-18	35	10.00	129.2	2700	0.200	39941
OL-194	535.1	S	1986	APR	30.62113	10	56	24.000	-18	33	0.00	129.2	1415	0.620	39943
PKS 1046-163	973.5	N	1986	MAY	3.65517	10	46	8.000	-16	21	7.00	124.2	2700	0.230	39190
OL-178	261.7	S	1986	MAY	4.02132	10	46	19.000	-15	52	0.00	123.6	1415	0.260	39201
MSH 10-118	266.6	N	1986	MAY	7.06364	10	39	24.000	-14	0	0.00	119.1	85	9.300	38809

OL-168	908.6	S	1986	MAY	7.00947	10	40	34.000	-13	50	0.00	119.2	1415	0.570	38879
OL-046	14.0	S	1986	MAY	17.92371	10	27	23.000	-9	24	0.00	105.2	1415	0.250	38122
OL-043	211.9	S	1986	MAY	23.08055	10	25	15.000	-8	4	0.00	99.5	1415	0.480	38016
DGVW047	310.3	N	1986	MAY	28.98923	10	23	36.000	-7	0	0.00	93.5	400	40.000	37936
OL-045	349.1	N	1986	JUN	15.77003	10	27	0.000	-5	24	0.00	77.0	1415	0.660	38102
OL-098.5	155.8	S	1986	AUG	15.10077	10	59	6.000	-6	37	0.00	29.5	1415	0.220	40134
MSH 11-007	3.5	S	1986	SEP	13.16396	11	16	6.000	-8	43	0.00	12.9	85	15.000	41472
PKS 1125-163	54.3	S	1987	JAN	6.65553	11	25	42.400	-16	22	55.00	105.6	2700	0.280	41995
OM-112	172.0	N	1987	JAN	28.69303	11	6	39.000	-16	7	0.00	130.2	1415	0.160	40769
OL-196	115.9	N	1987	FEB	6.53506	10	57	19.000	-15	38	0.00	139.9	1415	0.160	40005
OL-181	79.4	N	1987	FEB	14.56311	10	48	23.000	-15	2	0.00	148.1	1415	0.190	39320
PKS 1048-150	221.4	N	1987	FEB	14.48869	10	48	25.200	-15	4	38.00	148.0	2700	0.190	39321
OL-147.1	21.2	S	1987	MAR	4.61175	10	28	13.000	-13	12	0.00	158.8	1415	0.290	38168

END DATE: 1987 JUL 4.000

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END

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